Final

Environmental Impact Statement

for a

Geologic Repository for the Disposal of
Spent Nuclear Fuel and High-Level
Radioactive Waste at Yucca Mountain,
Nye County, Nevada

Volume I - Impact Analyses
Chapters 1 through 15

U.S. Department of Energy
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ABSTRACT: The Proposed Action addressed in this Final EIS is to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain in southern Nevada for the disposal of spent nuclear fuel and high-level radioactive waste currently in storage or projected to be generated at 72 commercial and 5 DOE sites across the United States. The EIS evaluates (1) projected impacts on the Yucca Mountain environment of the construction, operation and monitoring, and eventual closure of the geologic repository; (2) the potential long-term impacts of repository disposal of spent nuclear fuel and high-level radioactive waste; (3) the potential impacts of transporting these materials nationally and in the State of Nevada; and (4) the potential impacts of not proceeding with the Proposed Action. The preferred alternative is to proceed with the Proposed Action and to use mostly rail, both nationally and in Nevada, to transport spent nuclear fuel and high-level radioactive waste.

PUBLIC COMMENTS: In preparing this EIS, DOE considered comments received by letter, electronic mail, facsimile transmission, and oral and written comments given at public hearings at 21 locations across the United States on the Draft EIS, and at 3 locations in Nevada for the Supplement to the Draft EIS.

FOREWORD

The purpose of this environmental impact statement (EIS) is to provide information on potential environmental impacts that could result from a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at the Yucca Mountain site in Nye County, Nevada. The EIS also provides information on potential environmental impacts from an alternative referred to as the No-Action Alternative, under which there would be no development of a geologic repository at Yucca Mountain.

U.S. Department of Energy Actions

The Nuclear Waste Policy Act, enacted by Congress in 1982 and subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.

- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, accompany the recommendation. The Department of Energy (DOE) has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

Presidential Recommendation and Congressional Action

If, after a recommendation by the Secretary, the President considered the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may object to the recommendation of the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submits such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submits such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

Actions To Be Taken after Site Designation

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the recommendation of the site designation becomes effective. The NWPA requires the Nuclear Regulatory Commission to adopt DOE's Final EIS to the extent practicable as part of the Nuclear Regulatory Commission's decisionmaking on the License Application.

Decisions Related to Potential Environmental Impacts Considered in the EIS

This EIS analyzes a Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a No-Action Alternative, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action.

As part of the Proposed Action, which DOE has identified as its preferred alternative, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations, associated routes for heavy-haul trucks, and alternative corridors for a branch rail line.

DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, however, the Department has not identified a preference among the five potential rail corridors in Nevada.

If the Yucca Mountain site was approved (designated), DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail corridors in consultation with affected stakeholders, particularly the State of Nevada. In this example, DOE would announce a preferred corridor in the *Federal Register* and other media. No sooner than 30 days after the announcement of a preference, DOE would publish its selection of a rail corridor in a Record of Decision. A similar process would occur in the event that DOE selected heavy-haul truck as its mode of transportation in the State of Nevada. Other transportation decisions, such as the selection of a specific rail alignment within a corridor, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and appropriate National Environmental Policy Act reviews.

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1.1 Potential Actions and Decisions Regarding the Proposed Repository

This EIS analyzes a *Proposed Action* to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a *No-Action Alternative*, under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the NWPA, in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

PROPOSED REPOSITORY

DOE has used the term *proposed repository* as a convenience to indicate the relationship of a Yucca Mountain Repository to the Proposed Action of this EIS. DOE could not pursue the use of Yucca Mountain for a repository unless the Secretary of Energy decided to recommend approval of the site to the President and a Presidential site designation became effective. At that time, DOE would submit a License Application to the Nuclear Regulatory Commission seeking authorization to construct a repository at Yucca Mountain.

As part of the Proposed Action, which DOE has identified as its preferred *alternative*, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the impacts of rail and truck transportation nationally and in Nevada, as well as impacts in Nevada of alternative corridors for a branch rail line, routes for heavy-haul trucks, and alternative and associated *intermodal (rail-to-truck) transfer stations*.

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1.2 Radioactive Materials Considered for Disposal in a Monitored Geologic Repository

Commercial nuclear powerplants, which supply approximately 20 percent of the Nation's electricity, produce spent nuclear fuel. In addition, DOE manages a complex of large government-owned facilities that formerly produced nuclear weapons materials, and in doing so produced spent nuclear fuel and high-level radioactive waste. DOE also operates research reactors that produce spent nuclear fuel and processing facilities that produce high-level radioactive waste.

The following discussion describes spent nuclear fuel and high-level radioactive waste, including *mixed-oxide fuel* (a mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors) and immobilized plutonium forms. The discussion also identifies other waste forms, particularly Greater-Than-Class-C wastes and Special-Performance-Assessment-Required wastes, that are currently classified as *low-level radioactive* wastes but that could require disposal in a monitored geologic repository.

1.2.1 GENERATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

The material used to power commercial nuclear reactors typically consists of cylindrical fuel pellets made of uranium oxide. Fuel pellets are placed in tubes that are ordinarily about 3.7 meters (12 feet) long and 0.64 centimeter (0.25 inch) in diameter. Sealed tubes with fuel pellets inside them are called fuel rods (Appendix A). Fuel rods are arranged in bundles called fuel assemblies (see Figure 1-2), which are placed in a *reactor*.

In the reactor, neutrons from the fuel strike other uranium atoms, causing them to split into parts, and producing heat, radioactive *fission products,* and more free neutrons. This splitting of atoms is a form of nuclear reaction called *fission*. The neutrons produced by the fission process sustain the nuclear reaction by striking other uranium atoms in the fuel pellets, causing additional atoms to split. Control of the configuration and machinery associated with the fuel assemblies provides control of the rate at which fission occurs and, consequently, the amount of heat produced.

In a commercial power reactor, the heat that fission produces is used to convert water to steam. The steam turns turbine generators to produce electric energy. The reactors that power many naval vessels use the steam primarily to turn turbines to provide ship propulsion. Some research reactors also use the steam produced to generate electricity.

After a period in operation, enough of the fissile uranium atoms have undergone fission that the fuel is said to be "spent"; some of these spent nuclear fuel assemblies must be replaced with fresh fuel for operation to continue. During replacement, fresh fuel is placed in the reactor and spent fuel is placed in a pool of water. In commercial reactors, typical fuel cycles run 18 to 24 months, after which 25 to 50 percent of the spent nuclear fuel is replaced.

Nuclear reactor operators initially store spent nuclear fuel under water in spent fuel pools because of high levels of *radioactivity* and heat from *decay* of radionuclides. When the fuel has cooled and decayed sufficiently, operators can use two storage options: (1) continued in-pool storage or (2) above-ground *dry storage* in an independent installation. Thirty-three sites have existing or planned independent above-ground dry storage facilities. Dry storage includes the storage of spent nuclear fuel at reactor sites in approved storage casks.

Beginning in 1944, the United States operated reactors to produce materials such as plutonium for nuclear weapons. All of these reactors have been shut down for several years. When defense plutonium production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and generate plutonium. DOE used chemical processes (called *reprocessing*) to extract plutonium and other materials from spent nuclear fuel for defense purposes. One of the chemical byproducts remaining after reprocessing is high-level radioactive waste. The reprocessing of limited quantities of naval reactor fuels and some commercial reactor fuels, DOE test reactor fuels, and university research reactor fuels has also produced high-level radioactive waste.

Concerns about safety and environmental hazards contributed to DOE decisions to shut down parts of the weapons production complex in the 1980s. The shutdown, which became permanent due primarily to the reduced need for weapons materials at the end of the Cold War, included both production reactors and spent fuel reprocessing facilities. As a result, not all *DOE spent nuclear fuel* was reprocessed. Some of this fuel is now stored at DOE sites.

1.2.2 SPENT NUCLEAR FUEL

Spent nuclear fuel consists of nuclear fuel that has been withdrawn from a nuclear reactor following *irradiation,* provided that the constituent elements of the fuel have not been separated by reprocessing. *Commercial spent nuclear fuel* comes from nuclear reactors operated to produce electric power for domestic use. DOE manages spent nuclear fuel from DOE defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as fuel from university research reactors, commercial reactor fuel acquired by DOE for research and development, and fuel from foreign research reactors. Most nuclear fuel is encased in highly *corrosion-resistant cladding* before being placed in a reactor. The fuel remains in the cladding after it is irradiated and withdrawn as spent nuclear fuel. The purpose of the cladding is to protect the fuel in operating conditions associated with a reactor. Cladding, if it is not damaged or corroded, has the capability to isolate the spent nuclear fuel and delay the release of radionuclides to the environment for long periods.

Spent nuclear fuel is intensely radioactive in comparison to nonirradiated fuel and would be the primary source of radioactivity and heat generation in the proposed repository.

1.2.2.1 Commercial Spent Nuclear Fuel

Commercial spent nuclear fuel typically consists of uranium oxide fuel (which also contains actinides, fission products, and other materials), the cladding that contains the fuel, and the *assembly* hardware. The cladding for nuclear fuel assemblies is normally made of a *zirconium* alloy. However, about 1 percent of the spent nuclear fuel included in the Proposed Action is clad in stainless steel (Appendix A).

The sources of commercial spent nuclear fuel are the commercial nuclear powerplants throughout the United States. Figure 1-1 shows the locations of these sites. Appendix A, Section A.2.1, provides details on spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

Mixed-oxide fuel would be part of the commercial spent nuclear fuel inventory for the proposed repository. Section 1.2.4 includes a discussion of mixed-oxide fuel.

1.2.2.2 DOE Spent Nuclear Fuel

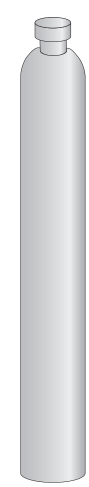
DOE spent nuclear fuel, like commercial spent nuclear fuel, has been withdrawn from a reactor following irradiation. Much of the DOE spent nuclear fuel is associated with past operations of reactors at the Hanford and Savannah River Sites that previously produced material for DOE's defense programs and research and development programs. These reactors are no longer operating. Smaller quantities of spent nuclear fuel have resulted from experimental reactor operations and from research conducted by approximately 55 university- and government-owned test reactors (see Appendix A). DOE spent nuclear fuel also includes spent fuel from reactors on nuclear-powered naval vessels and naval reactor prototypes.

DOE stores most of its spent nuclear fuel in pools or dry storage facilities at three primary locations: the Hanford Site in Washington State, the Idaho National Engineering and Environmental Laboratory in Idaho, and the Savannah River Site in South Carolina. Some DOE spent nuclear fuel is currently stored at the Fort St. Vrain dry storage facility in Colorado (see Figure 1-1). Additional small quantities remain at other locations. With the exception of Fort St. Vrain, which will retain its spent nuclear fuel in dry storage until disposition, DOE plans to ship all of the spent nuclear fuel for which it is responsible from other sites to one of the three primary locations mentioned above for storage and preparation for ultimate disposition [discussed in DIRS 103205-DOE (1995, all)]. This EIS does not analyze consolidation of spent nuclear fuel at DOE sites (see DIRS 101802-DOE 1995, all). Appendix A, Section A.2.2, provides details on DOE spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

1.2.3 HIGH-LEVEL RADIOACTIVE WASTE

DOE stores high-level radioactive waste in below-grade tanks at the Hanford Site, the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and the West Valley Demonstration Project in New York, a site presently owned by the New York State Energy Research and Development Authority (see Figure 1-1 for locations). High-level radioactive waste can be in a liquid, sludge, or saltcake form, and a solid immobilized glass form (see below). Liquid waste consists of water and organic compounds that contain dissolved salts. Sludge is a mixture of insoluble (that is, materials that will not dissolve in tank liquid) metallic salt compounds that precipitated and settled out of the solution after the waste became alkaline. Saltcake is primarily sodium and aluminum salt that crystallized from the solution following evaporation. High-level radioactive waste can also include other highly radioactive material that the Nuclear Regulatory Commission determines by rule to require permanent *isolation* (Nuclear Waste Policy Act definitions, Section 12), as well as immobilized plutonium waste forms. Appendix A, Section A.2.3, provides details on high-level radioactive waste and discusses the amount currently stored and projected to be stored at each site. Included in this total is immobilized high-level radioactive waste that will result from the electrometallurgical treatment of DOE sodium-bonded nuclear fuel at Argonne National Laboratory-West on the Idaho National Engineering and Environmental Laboratory site [*Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (65 *FR* 56565; September 19, 2000)].

The DOE process for preparing high-level radioactive waste for disposal starts with the transfer of the waste from storage tanks to a treatment facility. Treatment ordinarily includes separation of the waste into high-activity and low-activity fractions, followed by *vitrification* of the high-activity fraction. Vitrification involves adding materials to the waste and heating the mixture until it melts. The melted mixture is poured into canisters, where it cools into a solid glass or ceramic form that is very resistant to the leaching of radionuclides. The solidified, immobilized glass forms have been developed to keep the waste stable, confined, and isolated from the environment when inserted into disposal containers and disposed of in a monitored geologic repository. DOE will store the solidified high-level radioactive waste on the sites in *canisters* before eventual *shipment* to a repository. Figure 1-3 shows a representative vitrified high-level radioactive waste canister.



Note: There are two canister lengths - 120 inches and 180 inches.

Figure 1-3. Vitrified high-level radioactive waste canister.

The low-activity fraction does not meet the definition of high-level radioactive waste. It is classified as low-level waste and is therefore considered generally acceptable for near-surface disposal under separate low-level waste disposal regulations.

DOE has begun to solidify and immobilize waste at the Savannah River Site, has completed most solidification and immobilization at West Valley, and plans to begin solidification and immobilization at Hanford. DOE has prepared a Draft EIS (DIRS 155100-DOE 1999, all) to help it determine the method it will use to prepare high-level radioactive waste at the Idaho National Engineering and Environmental Laboratory for disposal.

1.2.4 SURPLUS WEAPONS-USABLE PLUTONIUM

DOE has declared some weapons-usable plutonium to be surplus to national security needs (DIRS 118979-DOE 1999, p. 1-1). This material includes purified plutonium, nuclear weapons components, and materials and residues that could be processed to produce purified plutonium (Appendix A, Section A.2.4). DOE currently stores these plutonium-containing materials at various sites throughout the United States.

DOE could emplace surplus weapons-usable plutonium in the repository in two forms. One form would be an immobilized plutonium ceramic that DOE would dispose of as high-level radioactive waste. The second form would be mixed uranium and plutonium oxide fuel (called mixed-oxide fuel) assemblies that would be used for power production in commercial nuclear reactors and disposed of in the same manner as other commercial spent nuclear fuel. The analysis in this EIS assumed that approximately one-third of the surplus plutonium would be immobilized and approximately two-thirds would be mixed-oxide spent nuclear fuel (Appendix A). The actual split could include the immobilization of between one-third and all of the plutonium. Appendix A, Section A.2.4, contains details on sources, generation and storage status, and material characteristics of this surplus plutonium.

1.2.5 OTHER WASTE TYPES WITH HIGH RADIONUCLIDE CONTENT

The Nuclear Regulatory Commission classifies most low-level radioactive waste into Classes A, B, and C (10 CFR Part 61), which reflect increasing levels of radioactivity. *Greater-Than-Class-C* is the term for radioactive waste generated by commercial activities that exceeds Nuclear Regulatory Commission concentration limits for Class C waste, as specified in 10 CFR Part 61. The Nuclear Regulatory Commission has determined that shallow land burial of Greater-Than-Class-C low-level radioactive waste generally is not acceptable. *Special-Performance-Assessment-Required* waste is DOE-generated low-level radioactive waste with radioactive content higher than Class C shallow land disposal limits.

1.3 National Effort To Manage Spent Nuclear Fuel and High-Level Radioactive Waste

This section provides background information on the management of spent nuclear fuel and high-level radioactive waste, and describes the Nuclear Waste Policy Act of 1982 and its amendments.

1.3.1 BACKGROUND

In the late 1950s, active investigation began on the concept of mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. In the 1970s, the United States reprocessed a small amount of commercial spent nuclear fuel to extract plutonium and studied the feasibility of expanded reprocessing. The plutonium would have been combined with uranium and used again as reactor fuel, substantially reducing the total amount of new enriched uranium required (DIRS 103414-NRC 1976, all). President Carter cancelled consideration of this approach, leaving disposal as the primary option for spent nuclear fuel.

In a February 12, 1980, message to Congress, President Carter stated that the safe disposal of radioactive materials generated by both defense and civilian nuclear activities is a national responsibility. In fulfillment of that responsibility, he announced a comprehensive program for the management of radioactive materials and adopted an interim planning strategy focusing on "the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel" (DIRS 104832-DOE 1980, p. 2.7). President Carter stated that he would reexamine this interim strategy and decide if changes were required after the completion of the environmental reviews required by the National Environmental Policy Act. As part of this reexamination, DOE issued the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DIRS 104832-DOE 1980, all). That EIS analyzed the environmental impacts that could occur if DOE developed and implemented various technologies for the management and disposal of spent nuclear fuel and high-level radioactive waste. It examined several alternatives, including mined geologic disposal, very deep hole disposal, disposal in a mined cavity that resulted from rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal, and no action. The 1981 Record of Decision for that EIS announced the DOE decision to pursue the mined geologic disposal alternative for the disposition of spent nuclear fuel and high-level radioactive waste (46 *FR* 26677; May 14, 1981).

Internationally, permanent geologic disposal is the consensus choice of technology for the management of commercial spent nuclear fuel. The United States remains committed to disposal of commercial and DOE spent nuclear fuel, DOE high-level radioactive waste, and surplus weapons-usable plutonium in a geologic repository. This commitment assumes the acceptance and disposal in a U.S. repository of certain spent nuclear fuel that contains uranium enriched in the United States that has been used in foreign research reactors. This approach supports the U.S. advocacy for limiting international trade in weapons-usable nuclear materials and signals the U.S. commitment to a policy of nonproliferation of nuclear materials.

1.3.2 NUCLEAR WASTE POLICY ACT

In 1983, Congress enacted the Nuclear Waste Policy Act (Public Law 97-425; 96 Stat. 2201), which acknowledged the Federal Government's responsibility to provide permanent disposal of the nation's spent nuclear fuel and high-level radioactive waste, and established the Office of Civilian Radioactive Waste Management, which has the responsibility to carry out the evaluative, regulatory, developmental, and operational activities the Act assigns to the Secretary of Energy. The Nuclear Waste Policy Act began a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process (shown in Figure 1-4), DOE identified nine candidate sites, the Secretary of Energy nominated five of the nine sites for further consideration, and DOE issued environmental assessments for the five sites in May 1986. DOE recommended three of the five sites (Deaf Smith County, the Hanford Site, and Yucca Mountain) for possible study as repository site candidates, and President Reagan approved the three as candidates. In addition, the Nuclear Waste Policy Act recognized a need to ensure that spent nuclear fuel and high-level radioactive waste now accumulating at commercial and DOE sites do not adversely affect public health and safety and the environment [NWPA, Section 111(a)(7)].

In 1987, Congress significantly amended the Nuclear Waste Policy Act. This Act, as amended (42 U.S.C. 10101 *et seq.*), which this EIS refers to as the NWPA, identified one of the three Presidentially approved candidate sites, Yucca Mountain, as the only site to be studied as a potential location for a geologic repository. Congress directed the Secretary of Energy to study the Yucca Mountain site and recommend whether the President should approve the site for development as a repository. Congress also required that a Final EIS accompany any Secretarial recommendation to approve the Yucca Mountain site to the President [NWPA, Section 114(a)(1)]. DOE has prepared this EIS to fulfill that requirement.

1.3.2.1 Requirement To Study and Evaluate the Site

In addition to the general responsibilities it establishes, the NWPA requires the Secretary of Energy specifically to characterize and evaluate the Yucca Mountain site for a geologic repository. The Act directs the Secretary of Energy to characterize only the Yucca Mountain site as a potential repository location and establishes a decisionmaking process to determine whether to designate Yucca Mountain as qualified for an application for repository construction authorization (NWPA, Sections 113, 114, 115, and 160).

Congress created the *Nuclear Waste Technical Review Board* as an independent organization to evaluate the technical and scientific validity of *site characterization* activities for the proposed repository and activities related to the packaging and transportation of spent nuclear fuel and high-level radioactive waste (NWPA, Section 503). The Nuclear Waste Technical Review Board must report findings, conclusions, and recommendations based on its evaluations to Congress and to the Secretary of Energy at least twice each year (NWPA, Section 508).

1.3.2.2 Elements of Site Evaluation

Sections 113, 114, and 115 of the NWPA contain specific and mostly sequential steps in the evaluation and decisionmaking process Congress has established for the Yucca Mountain site. The rest of this section and Section 1.3.2.3 describe that process.

The first steps in the evaluation and decisionmaking process for the Yucca Mountain site require the Secretary of Energy and, by extension, DOE, to gather data about Yucca Mountain and evaluate whether to recommend Yucca Mountain for approval as the site for a *license application* to the Nuclear Regulatory Commission for repository development. The Secretary's specific duties include:

- Undertake physical characterization of the Yucca Mountain site.
- Hold public hearings in the Yucca Mountain site *vicinity*.
- Prepare a description of the site, of spent nuclear fuel and high-level radioactive waste forms and packaging to be used, and of site safety.
- Decide whether to make a recommendation to the President on approval of the site for development as a repository.

Section 1.4.3.7 describes the elements that the Secretary of Energy must develop and consider in making a *site recommendation* to the President and in providing a statement of the basis for that recommendation.

The NWPA directs the Secretary of Energy to evaluate a *scenario* under which DOE would place an inventory of material in the proposed Yucca Mountain Repository. This EIS considers a repository inventory of 70,000 *metric tons of heavy metal (MTHM)* comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE spent nuclear fuel and high-level radioactive waste. This overall inventory includes surplus weapons-usable plutonium as spent mixed-oxide fuel and immobilized plutonium. Appendix A provides additional details of the inventory of materials.

Operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel through 2046. The total projected DOE inventory of materials includes 2,500 MTHM of spent nuclear fuel and approximately 22,280 canisters of high-level radioactive waste. Chapter 8 evaluates potential consequences of using a repository at Yucca Mountain to dispose of all spent nuclear fuel and high-level radioactive waste that could be produced through 2046 for which DOE retains ultimate responsibility.

1.3.2.3 Site Qualification and Authorization Process

1.3.2.3.1 *U.S. Department of Energy Actions*

The Nuclear Waste Policy Act of 1982, subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, would accompany the recommendation. DOE has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

1.3.2.3.2 *Presidential Recommendation and Possible State and Congressional Action*

If, after any recommendation by the Secretary, the President considered the site qualified for an application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may disapprove the site designation by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submit such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submitted such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

1.3.2.3.3 *Actions After Site Designation*

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the site designation becomes effective. The NWPA requires the Commission to adopt DOE's Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

1.3.2.4 Environmental Protection and Approval Standards for the Yucca Mountain Site

Section 121 of the Nuclear Waste Policy Act of 1982 directed the U.S. Environmental Protection Agency to establish generally applicable standards to protect the general environment from *offsite* releases from radioactive materials in repositories and directed the Nuclear Regulatory Commission to issue technical requirements and criteria for such repositories. In 1992, Congress modified the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission in relation to a possible repository at Yucca Mountain. Section 801(a) of the Energy Policy Act of 1992 directed the Environmental Protection Agency to retain the National Academy of Sciences to conduct a study and issue findings and recommendations on setting reasonable standards for protecting public health and safety in relation to a repository at Yucca Mountain. Section 801(a) also directs the Environmental Protection Agency to establish Yucca Mountain-specific standards based on and consistent with the Academy's findings and recommendations.

The National Academy of Sciences issued its findings and recommendations in a 1995 report (DIRS 100018-National Research Council 1995, all). The Environmental Protection Agency has issued standards for both storage and disposal of radioactive material at Yucca Mountain (40 CFR Part 197). The standards set health-based limits and *groundwater* protection limits for any radioactive releases from a repository at Yucca Mountain.

This EIS includes evaluation of the proposed Yucca Mountain repository's capability to satisfy the Environmental Protection Agency's regulations. Chapter 11 contains a more detailed discussion of these regulations and other requirements.

Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to revise its general technical requirements and criteria for geologic repositories (10 CFR Part 60) to be consistent with the Environmental Protection Agency site-specific Yucca Mountain standards established at 40 CFR Part 197. The Nuclear Regulatory Commission has issued site-specific technical requirements and criteria (10 CFR Part 63). The Commission would use these requirements and criteria to evaluate an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to close and decommission such a repository.

The Nuclear Waste Policy Act of 1982 required the Secretary of Energy to issue general guidelines for use in recommending potential repository sites for detailed site characterization. DOE issued these guidelines in 1984 (10 CFR Part 960).

DOE has established site-specific regulations (10 CFR Part 963) that provide a portion of the basis for the evaluation of site suitability, as provided in the NWPA. The EIS provides current information on the proposed repository and presents an evaluation of the repository site, potential repository development, and anticipated repository performance measured against human health and other relevant technical criteria. DOE will comply with all applicable environmental and approval standards for the Yucca Mountain site.

1.4 Yucca Mountain Site and Proposed Repository

Spent nuclear fuel and high-level radioactive waste generate large amounts of *radiation* from the gradual decay of radioactive isotopes. These isotopes have the potential to cause severe human health impacts. In addition, the materials can generate heat from *radioactive decay* for periods lasting thousands of years. The Nuclear Waste Policy Act directs DOE to analyze and consider the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository.

1.4.1 YUCCA MOUNTAIN SITE

The site of the proposed Yucca Mountain Repository (see Figure 1-5) is on lands administered by the Federal Government in a remote area of the Mojave Desert in Nye County in southern Nevada, approximately 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The area surrounding the site is sparsely populated and receives an average of about 170 millimeters (7 inches) of precipitation per year. Chapter 3, Section 3.1, provides detailed information on the environment at the site.

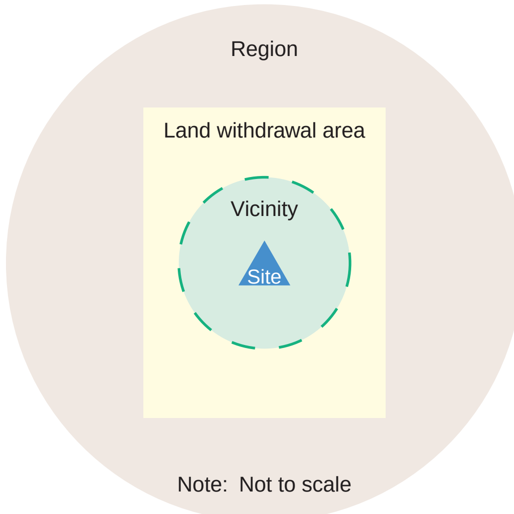
SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.



Controlled Area (as defined in 40 CFR Part 197) *(not shown on illustration):* The area surrounding the repository that is restricted to public access for the long term, as identified by passive institutional controls that DOE would install at closure. The controlled area could include as much as 300 square kilometers (about 120 square miles) surface and subsurface area. It would extend no more than 5 kilometers (3 miles) in any direction from the repository footprint except in the predominant direction of groundwater flow, where the controlled area would extend no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude, the present latitude of the southwest corner of the Nevada Test Site [about 18 kilometers (11 miles)].

The Yucca Mountain site has several characteristics that would be expected to limit possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. It is isolated from concentrations of human population and human activity and is likely to remain so. The very *arid* climate results in a relatively small volume of water that can move as groundwater in the mountain's unsaturated zone. The groundwater table sits substantially below the level at which DOE would locate a repository, providing additional separation between water sources and materials emplaced in waste packages. Maximizing the separation of water from the repository would minimize corrosion and would delay any mobilization and transport of radionuclides from the repository, as discussed in Chapter 5.

Groundwater from Yucca Mountain flows into a closed, sparsely populated hydrogeologic basin. A closed basin is one in which water introduced into the basin by rain cannot flow out the basin to any river or ocean. This closed basin provides a *natural barrier* to a general spread of radionuclides in the event that radioactive *contamination* reached the groundwater.

The *land withdrawal area* analyzed in the EIS includes about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the U.S. Department of Defense, and the U.S. Department of the Interior (see Figure 1-6). Approximately as many as 6.0 square kilometers (1,500 acres) comprising the repository site would be needed for development of surface repository facilities, with the remainder serving as a large buffer zone. If Yucca Mountain is recommended and approved for development as a repository, all or a portion of the land withdrawal area would have to be withdrawn permanently from public access to satisfy Nuclear Regulatory Commission licensing requirements at 10 CFR 60.121. If the land to be withdrawn included land that this EIS does not consider for withdrawal, DOE would perform additional analysis as required by the National Environmental Policy Act.

1.4.2 PROPOSED DISPOSAL APPROACH

The proposed monitored geologic repository at Yucca Mountain would be a large underground excavation with a network of *drifts* (tunnels) serving as the *emplacement* area for spent nuclear fuel and high-level radioactive waste. Rail, *legal-weight trucks,* or heavy-haul trucks would provide most of the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to the repository. Barges could move spent nuclear fuel from some sites to rail and truck transfer points. Shippers would transport the materials in Nuclear Regulatory Commission-approved shipping containers designed to transport radioactive materials with minimal risk to the public health and safety and to the environment. (Chapter 6 discusses potential transportation systems.) Figure 1-7 shows the concept of temporary storage of spent nuclear fuel and high-level radioactive waste at storage sites, transporting these materials to the proposed repository, and disposing of the materials in an emplacement area.

At the repository, the material would be loaded in disposal containers. The filled disposal containers would be sealed, thereby becoming waste packages. The waste packages would be moved underground by rail. Remote-controlled handling vehicles would place the waste packages in emplacement drifts. The waste packages, which would be designed to remain intact for thousands of years (at a minimum), would be part of an *engineered barrier system* inside the mountain that would isolate spent nuclear fuel and high-level radioactive waste from the environment. The engineered barrier system, together with the geologic and hydrologic properties of the Yucca Mountain site, would ensure that a potential release of radioactive material after repository *closure* would meet applicable performance standards to contain and isolate the waste for 10,000 years or more. Chapter 5 provides detailed discussions of the *natural system* and of waste packages. Chapter 2 describes the Proposed Action at Yucca Mountain in additional detail, including the transportation activities required to move the spent nuclear fuel and high-level radioactive waste to the site.

Under the NWPA, the proposed repository, if authorized, would be a facility for the permanent disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. The Nuclear Waste Policy Act requires the Nuclear Regulatory Commission to include in the authorization a prohibition against the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Nuclear Waste Policy Act, Section 114(d)]. DOE has allocated 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM equivalent of DOE spent nuclear fuel and high-level radioactive waste to the proposed repository at Yucca Mountain. The Proposed Action that this EIS evaluates, therefore, includes the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to Yucca Mountain and the emplacement of as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the proposed repository. Chapter 8 of this EIS analyzes cumulative impacts from the disposal at Yucca Mountain of all spent nuclear fuel and high-level radioactive waste projected to be produced through 2046 for which DOE will retain ultimate responsibility. Chapter 8 also considers the disposal of *Greater-Than-Class-C waste* and *Special-Performance-Assessment-Required waste* at Yucca Mountain.

1.4.3 DOE ACTIONS TO EVALUATE THE YUCCA MOUNTAIN SITE

DOE has performed site characterization activities at Yucca Mountain for almost two decades, and has issued several documents related to those studies, in addition to the Draft EIS, Supplement to the Draft EIS, and this Final EIS, that would form part of the basis for a potential Site Recommendation. The following sections address these activities and reports, and provide a brief description of the No-Action Alternative.

1.4.3.1 Site Characterization Activities

In accordance with the NWPA [Section 113(b)], the DOE Office of Civilian Radioactive Waste Management prepared a Site Characterization Plan for the Yucca Mountain site (DIRS 100282-DOE 1988, all). DOE has had a program of investigations and evaluations to assess the suitability of the Yucca Mountain site as a potential geologic repository and to provide information for this EIS. The program consists of scientific, engineering, and technical studies and activities.

Examples of activities, investigations, and evaluations associated with site characterization include the following:

- Construction of an *Exploratory Studies Facility,* including the North and South *Portal* Ramps (openings into the mountain)
- Excavation of underground tunnels and rooms in the Exploratory Studies Facility for scientific and engineering studies, testing, and experiments
- Investigations of such topics as *hydrology,* including groundwater characteristics; general site geology; and specific geologic issues such as erosion, *seismicity,* and volcanic activity
- Field monitoring, including *air quality*, meteorological, radiological, and water resources monitoring
- Cultural resources studies, including Native American interests
- Terrestrial ecosystem studies

1.4.3.2 Viability Assessment

In the *Viability Assessment of a Repository at Yucca Mountain (Viability Assessment)* (DIRS 101779-DOE 1998, all), DOE evaluated a preliminary design based on scenarios that focused on the amount of spent nuclear fuel (and associated thermal output) that DOE would emplace per unit area of the repository. This concept was called *areal mass loading*. For analytical purposes, areal mass loading was represented in the Viability Assessment and in the Draft EIS by a high thermal load scenario, an intermediate thermal load scenario, and a low thermal load scenario. DOE selected these scenarios to represent the range of foreseeable design alternatives, and to ensure that it considered the associated range of potential environmental impacts. The Viability Assessment included the following:

- Preliminary design scenarios for critical elements of the repository and *waste package*
- A *total system performance assessment,* based on the design concept and the scientific data and analyses available by 1998, that described the probable behavior of the repository in the Yucca Mountain geologic setting

- A plan and cost estimate for the remaining work required to complete and submit a License Application to the Nuclear Regulatory Commission
- An estimate of the costs to construct and operate the repository in accordance with the design concept

The Draft EIS summarized results from the Viability Assessment, where applicable. DOE did not intend the scenarios studied in the Viability Assessment to place limits on choices among alternative designs. DOE expected the repository design to continue to evolve in response to ongoing site characterization and design-related evaluations.

1.4.3.3 Yucca Mountain Science and Engineering Report

Since the publication of the Draft EIS, DOE has continued to evaluate design features and operating modes that would improve long-term repository performance, reduce uncertainties in performance, and improve operational safety and efficiency. DOE documented the design evolution process in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (Science and Engineering Report; DIRS 153849-DOE 2001, all). The result of the process was the Science and Engineering Report Flexible Design (which this Final EIS calls the *flexible design*). DOE evaluated the flexible design in a Supplement to the Draft EIS, released for public review and comment in May 2001.

The Yucca Mountain Science and Engineering Report describes:

- Waste forms to be disposed of
- Results of scientific and engineering studies completed to date
- The flexible design for the repository (preliminary engineering specifications)
- A range of repository operating modes under the flexible design
- Waste package designs (preliminary engineering specifications)
- Results of recent assessments of the long-term performance of the potential repository (Total System Performance Assessment)

The Science and Engineering Report documents information that the Secretary of Energy will use to determine whether to recommend approval of the Yucca Mountain site to the President, including scientific investigations, site characterization studies, and evaluation of how conditions might evolve over time. In the flexible design, the basic elements of the proposed action, to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged. The flexible design provides the capability to operate the repository in a range of operating modes to affect conditions of temperature and associated humidity. The *higher-temperature repository operating mode* would raise at least portions of the rock walls between the emplacement drifts to a maximum temperature above 96ºC (205ºF), which is the boiling point of water at the repository elevation. The *lower-temperature operating mode* incorporates a range of scenarios that include conditions under which the surface temperature of emplaced waste packages would not exceed 85ºC (185ºF).

The Science and Engineering Report was issued in May 2001 for public comment. At the time of preparation of this Final EIS, DOE was revising this report to address these comments.

1.4.3.4 Preliminary Site Suitability Evaluation

Following the Science and Engineering Report, DOE released the *Yucca Mountain Preliminary Site Suitability Evaluation* (DIRS 155734-DOE 2001, all). The Preliminary Site Suitability Evaluation presents currently available information to support a preliminary evaluation of the suitability of the Yucca Mountain site for a monitored geologic repository and describes preliminary results of DOE's evaluation of whether the site is suitable for such a repository.

The Preliminary Site Suitability Evaluation compares the preliminary results of DOE's evaluation with DOE's proposed (since promulgated) site suitability guidelines. These preliminary results indicated that a potential repository at Yucca Mountain would likely meet Environmental Protection Agency radiation protection standards and proposed (since promulgated) Nuclear Regulatory Commission regulations for protecting people and the environment.

The purpose of the information provided in the Preliminary Site Suitability Evaluation is to aid the public in its review and comments on this aspect of the bases for the Secretary of Energy's consideration of a possible Site Recommendation.

The Preliminary Site Suitability Evaluation was issued in August 2001 for public comment. At the time of preparation of this Final EIS, DOE was revising this document to address these comments.

1.4.3.5 Supplemental Science and Performance Analyses

DOE has also issued the *Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all; DIRS 154659-BSC 2001, all). This document describes supplemental analyses that have been conducted on long-term repository performance, incorporating those analyses into a supplemental Total Systems Performance Analysis (TSPA). The *Supplemental Science and Performance Analyses* first describes technical work conducted in each process model area and modifications to the Total System Performance Assessment model, and then describes the performance assessment analyses and results based on the technical work and model modification.

1.4.3.6 Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation

DOE has issued the *Total System Performance Assessment – Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain – Input to Final Environmental Impact Statement and Site Suitability Evaluation* (DIRS 157307-BSC 2001, all). This assessment integrates information from all previous long-term performance models and provides further modification to the *Supplemental Science and Performance Analyses.* The results from this assessment, which are the most current available at the time of Final EIS production, directly support the long-term performance evaluation in the Final EIS.

1.4.3.7 Site Recommendation

Section 114(a) of the Nuclear Waste Policy Act requires that any recommendation by the Secretary of Energy be based on the record of information developed during site characterization and be submitted to the President together with a comprehensive statement of the basis of that recommendation. The recommendation is to be supported by:

- A description of the proposed repository, including preliminary engineering specifications for the facility

- A description of the *waste form* or packaging proposed for use at the repository, and an explanation of the relationship between such waste form or packaging and the geologic medium of the site
- A discussion of data obtained in site characterization activities that relate to the safety of the site
- A Final EIS prepared for the Yucca Mountain site accompanied by comments from the Department of the Interior, the Council on Environmental Quality, the Environmental Protection Agency, and the Nuclear Regulatory Commission
- The preliminary comments of the Nuclear Regulatory Commission on the extent to which the waste form proposal and the at-depth site characterization analysis seem to be sufficient for inclusion in a License Application
- The views and comments of the governor and legislature of any state and of the governing bodies of affected Native American tribes, together with responses from the Secretary of Energy to such views
- Any impact report submitted under Section 116(c)(2)(B) of the NWPA by the State of Nevada
- Other information the Secretary considers appropriate

1.4.3.8 No-Action Alternative

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and begin site *decommissioning* and reclamation. The commercial utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, in a condition ready for shipment to a repository. The potential environmental impacts from two No-Action scenarios, described below, serve as a basis for comparison to the potential environmental impacts of the Proposed Action.

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites under *institutional control* for at least 10,000 years.
- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

INSTITUTIONAL CONTROL

Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

DOE recognizes that neither scenario would be likely if there was a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a basis for comparison to the Proposed Action. There are a number of possibilities that DOE could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of alternatives to deep geologic disposal. One such centralized storage possibility, the proposed Private Fuel Storage Facility for commercial spent nuclear fuel in Utah, is currently in the Nuclear Regulatory Commission licensing process. The Commission issued a Final EIS in January 2002, however, that document was unavailable for use during the preparation of this Final EIS. The Commission has yet to issue a decision on whether to grant a license.

1.5 Environmental Impact Analysis Process

The National Environmental Policy Act of 1969, as amended, and regulations promulgated by the Council on Environmental Quality established procedures for Federal agencies to use when preparing an EIS. A major emphasis of the EIS process is to promote public awareness of the proposed actions and provide opportunities for public involvement. An agency prepares an EIS in a series of steps: (1) soliciting comments from Federal and state agencies, stakeholders, Tribal Nation representatives, and the general public to assist in defining the proposed action, alternatives, and issues requiring analysis (a process known as *scoping*); (2) preparing a Draft EIS for public distribution and comment; (3) receiving and responding to agency and public comments on the Draft EIS; and (4) preparing a Final EIS that incorporates or summarizes (if the public comments are exceptionally voluminous) and responds to public comments on the Draft EIS.

The NWPA includes specific provisions relevant to this EIS. Under the NWPA, the Secretary is not required to consider in this EIS (1) the need for a geologic repository, (2) the time at which a repository could become available, and (3) alternatives to isolating spent nuclear fuel and high-level radioactive waste in a repository. The fourth provision addresses the issue of potential alternative sites by providing that the EIS does not need to consider any site other than Yucca Mountain for repository development [NWPA, Section 114(f)(2) and (3)]. DOE has focused the EIS analysis on two alternatives: (1) the Proposed Action of constructing, operating and *monitoring*, and eventually closing a repository at Yucca Mountain, and (2) the No-Action Alternative, which assumes that site characterization activities at Yucca Mountain would end, and that spent nuclear fuel would remain at commercial sites and spent nuclear fuel and high-level radioactive waste would remain at DOE facilities.

1.5.1 DRAFT EIS AND SUPPLEMENT TO THE DRAFT EIS PROCESS

1.5.1.1 Notice of Intent and Scoping Meetings

The EIS scoping process is intended to determine the scope and the significant issues to be analyzed in depth in the EIS. The scoping process should begin early and be open, and include public notice of public meetings and of the availability of environmental documents to inform those persons and agencies who might be interested in or affected by a proposed action.

On August 7, 1995, DOE published a Notice of Intent announcing that it would prepare an EIS for a proposed repository at Yucca Mountain, Nevada (60 *FR* 40164, August 7, 1995). To encourage broad participation by the public, before publishing the Notice of Intent DOE notified its stakeholders, the media, Congressional representatives, the Office of the Governor of Nevada, affected units of local government in the Yucca Mountain site vicinity, the Nuclear Regulatory Commission, and other Federal agencies such as the Bureau of Land Management, National Park Service, and the Nuclear Waste Technical Review Board of its plans to prepare the EIS and its approach to the scoping process.

To reach minority and low-income communities, DOE contacted news publications and radio stations that tend to service these communities to notify them of the scoping meetings and the locations of available information. In addition, DOE met with 13 Native American tribes and organizations and provided them the same information. DOE invited public interest groups, transportation interests, industry and utility organizations, regulators, and members of the general public to participate in the process. The Department mailed a series of information releases to Yucca Mountain stakeholders notifying them of the opportunity to comment on the scope of the EIS; sent press releases and public service announcements to newspapers and television and radio stations; and made information about Yucca Mountain, the EIS, and the scoping process available on the Internet (at *www.ymp.gov*) and in public reading rooms around the country.

In 1995, DOE held 15 public scoping meetings across the country (DIRS 104630-YMP 1997, p. 7). More than 500 people submitted more than 1,000 comment documents during the 120-day public scoping period. DOE considered all comments—oral and written—it received during the scoping process and grouped them in categories in the *Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DIRS 104630-YMP 1997, all).

PUBLIC SCOPING MEETING LOCATIONS

Sacramento, California
Denver, Colorado
College Park, Georgia (near Atlanta)
Boise, Idaho
Chicago, Illinois
Linthicum, Maryland (near Baltimore)
Kansas City, Missouri
Caliente, Nevada
Las Vegas, Nevada
Pahrump, Nevada
Reno, Nevada
Tonopah, Nevada
Troy, New York (near Albany)
Dallas, Texas
Salt Lake City, Utah

Several comments led to modifications in the scope of the EIS. The two most notable changes were the consideration of additional inventories such as the total projected inventory of spent nuclear fuel and high-level radioactive waste and other wastes that might require permanent isolation (see Section 1.5.1.2), and the addition of new Nevada transportation route alternatives. A number of commenters asked that the EIS discuss the history of the Yucca Mountain site characterization program and requirements of the NWPA; address DOE's responsibility to begin accepting waste in 1998 (including an analysis of the potential for receipt of spent nuclear fuel and high-level radioactive waste prior to the start of emplacement); describe the potential decisions that the EIS would support; and examine activities other than *construction, operation and monitoring,* and eventual closure of a repository at Yucca Mountain.

Other concerns raised by the public during scoping emphasized that DOE needed to ensure that the EIS thoroughly addresses the impacts of constructing and operating a geologic repository and related facilities (including the use of a rail line, heavy-haul truck routes, and intermodal transfer stations) on:

- Land uses in the Yucca Mountain vicinity (including consistency with existing land-use plans)
- Regional air quality and meteorology
- Geology (including the effects of earthquakes and volcanism and the potential for transport of radioactive and hazardous materials from the repository)
- Regional hydrology (including groundwater quality in Amargosa Valley, Ash Meadows, and Death Valley National Park)
- Biological resources (including postclosure effects on wildlife from potential increased surface temperatures)
- Health and safety (including past radiation exposures from activities at the Nevada Test Site for both pre- and postclosure periods)
- Long-term performance assessment for the repository (including an evaluation of the ability of the overall system to meet potential performance objectives, waste package performance and degradation given different thermal loads, *infiltration* rates, corrosion models, and other relevant factors)
- Sabotage and safeguards and security measures during waste transport and disposal

- Cultural and historic resources and *environmental justice*
- Socioeconomics
- *Mitigation* (including the mitigation of impacts from both routine operations and *accident* conditions)

DOE included discussions and analyses in the EIS that respond to these public issues and concerns.

DOE received many requests for more formal involvement in the EIS preparation process by representatives of the affected units of local government and Native American tribes. During the preparation of the EIS, DOE held discussions with a number of government agencies and other organizations to discuss issues of concern, obtain information for inclusion or analysis in the EIS, and initiate consultation or permit processes. DOE tasked (and funded) the American Indian Writers Subgroup to prepare a document setting forth Native American viewpoints and concerns regarding the repository and Yucca Mountain; that document (DIRS 102043-AIWS 1998, all) is quoted and referenced in the EIS. A similar opportunity was extended to the State of Nevada and the affected units of local government to prepare their own documents setting forth perspectives and views on a variety of issues of local and regional concern, which DOE agreed to incorporate by reference in the EIS. At the time the Draft EIS was issued, Nye County (DIRS 103099-Buqo 1999, all) had prepared such a document. In addition, other documents related to the Yucca Mountain region have been prepared in the past by several local government units including Clark, Lincoln, and White Pine Counties.

Some of the scoping comments raised issues and concerns that were not germane to the Proposed Action or the No-Action Alternative, such as the constitutional basis for waste disposal in Nevada. DOE acknowledged such issues and concerns in the summary of public scoping comments (DIRS 104630-YMP 1997, all), but did not analyze them in the EIS.

1.5.1.2 Additional Inventory Studies

The Proposed Action is to construct, operate and monitor, and eventually close a geologic repository for the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. During the scoping period, DOE received many comments that noted the potential existence of more than 70,000 MTHM of these materials and encouraged DOE to evaluate the total projected inventory. For example, presently operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel eligible for disposal by 2046 if all currently operating commercial licenses were extended for 10 additional years. Recently approved license extensions have been for 20 years, but some plant licenses might not be extended. In addition, some commenters requested that the EIS evaluate the disposal of radioactive waste types that might require permanent isolation, such as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste. For these reasons, DOE has included in the EIS *cumulative impact* analysis an evaluation of the cumulative environmental impacts that could occur as a result of the disposal of all projected spent nuclear fuel and high-level radioactive waste and the disposal of quantities of Greater-Than-Class-C and Special-Performance-Assessment-Required waste in the Yucca Mountain Repository (see Chapter 8).

1.5.1.3 Additional Nevada Transportation Analyses

In response to public comments, DOE decided to analyze a fifth branch rail line and a fifth route for heavy-haul trucks in Nevada. The Department added analyses of the Caliente-Chalk Mountain branch rail line and the Caliente/Chalk Mountain route for heavy-haul trucks to the analyses of four rail corridors and four heavy-haul truck routes it had previously identified for potential transportation impacts in Nevada. Chapter 6 and Appendix J describe the transportation analyses. The U.S. Air Force opposes the use of

APPROXIMATE WASTE INVENTORIES
(Measurement methods differ among waste types)

Commercial spent nuclear fuel
- Projected total: 105,000 MTHM in 2046
- Current disposal plan: 63,000 MTHM (includes plutonium disposed of as mixed-oxide fuel)

DOE spent nuclear fuel
- Projected total: 2,500 MTHM
- Current disposal plan: 2,333 MTHM (one-third of the 7,000-MTHM total of DOE material proposed for disposal, which includes high-level radioactive waste)

High-level radioactive waste
- Projected total: 22,280 canisters (would include immobilized plutonium to be disposed of as stated in current disposal plans)
- Current disposal plan: 8,315 canisters (includes approximately one third of the surplus plutonium inventory)

Greater-Than-Class-C waste
- Projected total: 2,100 cubic meters
- Disposal evaluated in Chapter 8

Special-Performance-Assessment-Required waste
- Projected total: 4,000 cubic meters
- Disposal evaluated in Chapter 8

the Caliente-Chalk Mountain rail corridor and heavy-haul truck route because of national security concerns; at this time DOE regards these routes as nonpreferred alternatives.

1.5.1.4 Draft EIS Public Comment Process

On August 6, 1999, DOE issued the *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*. DOE made the document available in 38 reading rooms throughout the country, sent copies to those who requested them, and made an electronic copy available on the Internet. On the same day, the Department began a public comment period on the Draft EIS originally scheduled to end on February 9, 2000, and later extended until February 28, 2000. DOE accepted all comments on the Draft EIS, including written, oral, and electronic comments through August 31, 2001. DOE held public hearings in 21 locations across the country and throughout the State of Nevada and also held a hearing in Las Vegas to take comments from members of Native American Tribes in the region. More than 700 persons provided formal comments at those hearings. In total, DOE received more than 11,000 comments from more than 2,300 commenters on the Draft EIS.

Draft EIS Public Hearing Locations

Amargosa Valley, Nevada
Goldfield, Nevada
College Park (Atlanta), Georgia
Austin, Nevada
Boise, Idaho
Caliente, Nevada
Carson City, Nevada
Chicago, Illinois
Cleveland, Indiana
Crescent Valley, Nevada
Denver, Colorado
Ely, Nevada
Las Vegas, Nevada
Lincoln, Nebraska
Lone Pine, California
Pahrump, Nevada
Reno, Nevada
Salt Lake City, Utah
San Bernardino, California
St. Louis, Missouri
Washington, DC

DOE has prepared a Comment-Response Document (Volume III of this Final EIS) that addresses the issues raised during the public comment period. The Comment-Response Document contains each comment (as an individual comment or summarized with similar comments) and the DOE response to each comment. DOE has incorporated changes to the Draft EIS analysis resulting from the comments in this Final EIS.

1.5.1.5 Supplement to the Draft EIS

As DOE anticipated and described in the Draft EIS, the design for the proposed repository continued to evolve. To present the latest design information to *decisionmakers* and the public, on May 11, 2001, DOE issued the *Supplement to the Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, and began a 45-day public comment period on the Supplement. Based on requests from a variety of sources, the Department subsequently extended the comment period until July 6, 2001. In June, 2001, during a review of its administrative records, DOE discovered that it had inadvertently not sent the Supplement to the Draft EIS to about 700 stakeholders who had requested and received a copy of the Draft EIS. The Department announced this oversight (66 *FR* 34623; June 29, 2001), sent the Supplement to the Draft EIS to these stakeholders, and provided them an opportunity to submit comments during a separate 45-day comment period (June 29 to August 13, 2001). DOE has presented and responded to all comments on the Supplement to the Draft EIS received by August 31, 2001. All comments received after August 31, 2001, were responded to as time and resources permitted. However, all comments received after August 31, 2001, whether or not responded to, were considered by the Department. Based on this consideration, the Department concluded that none raised new issues not already reflected in timely comments and already considered.

The scope of the Supplement was limited to presenting the latest design information and presenting the expected environmental impacts that could result from the evolved design. DOE held three public hearings on the Supplement to the Draft EIS. The Department received approximately 1,900 written, oral, and electronic comments on the Supplement. The Final EIS incorporates the information from the Supplement. The Comment-Response Document (Volume III of this Final EIS) includes public comments on the Supplement, and responses to those comments. Changes to the analysis of the proposed repository project caused by those comments and responses are captured in Volumes I, II, and IV.

Supplement to the Draft EIS Public Hearing Locations

Amargosa Valley, Nevada
Las Vegas, Nevada
Pahrump, Nevada

1.5.2 CONFORMANCE WITH DOCUMENTATION REQUIREMENTS

DOE has performed formal documented reviews of data to identify gaps, inconsistencies, omissions, or other conditions that would cause data to be suspect or unusable.

DOE planned analyses to ensure consistency and thoroughness in the environmental studies conducted for this EIS. DOE has also used configuration control methods to ensure that EIS inputs are current, correct, and appropriate, and that outputs reflect the use of appropriate inputs.

All work products for this EIS have undergone documented technical, editorial, and managerial reviews for adequacy, accuracy, and conformance to project and DOE requirements. Work products related to impact analyses (for example, calculations, data packages, and data files) have also undergone formal technical and managerial reviews. Calculations (manual or computer-driven) generated to support impact analyses have been verified in accordance with project management procedures.

1.5.3 RELATIONSHIP TO OTHER ENVIRONMENTAL DOCUMENTS

A number of completed, in-preparation, or proposed DOE National Environmental Policy Act documents relate to this EIS. In addition, other Federal agencies have prepared related EISs. Consistent with Council on Environmental Quality regulations that implement the National Environmental Policy Act, DOE has used information from these documents in its analysis and has incorporated this material by reference as appropriate throughout this EIS. Table 1-1 lists the documents that formed a basis for decisions associated with a geologic disposal program and investigation of Yucca Mountain as a potential repository site; these include the EIS for Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, all), the Surplus Plutonium Disposition EIS (DIRS 118979-DOE 1999, all), and the Yucca Mountain Site Environmental Assessment (DIRS 100136-DOE 1986, all).

Table 1-1. National Environmental Policy Act documents and Records of Decision related to the proposed Yucca Mountain Repository[a] (page 1 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities		
Final EIS, Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, all)	Commercial SNF; DOE SNF and HLW	Examines different disposal alternatives. ROD documented DOE decision to pursue geologic disposal for SNF and HLW.
EA, Yucca Mountain Site, Nevada Research and Development Area (DIRS 100136-DOE 1986, all)	Commercial SNF; DOE SNF and HLW	Examines impacts of site characterization activities and possible geologic repository at Yucca Mountain.
Final Supplemental EIS, Defense Waste Processing Facility, Savannah River Site, Aiken, South Carolina (DIRS 103191-DOE 1994, all)	HLW	Examines impacts of constructing and operating DWPF, which processes HLW at SRS. SRS HLW could be eligible for repository disposal.
Final EIS, Waste Management, Savannah River Site (DIRS 103207-DOE 1995, all)	HLW	Examines impacts of managing five types of waste (including liquid HLW) at SRS over 10 years. SRS HLW could be eligible for repository disposal.
Final EIS, Interim Management of Nuclear Materials at the Savannah River Site (DIRS 103209-DOE 1995, all)	HLW	Examines impacts of stabilization and interim storage of plutonium, uranium, and other nuclear materials. SRS SNF and HLW could be eligible for repository disposal.
Final EIS, Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington (DIRS 103213-DOE 1996, all)	DOE SNF	Examines impacts of managing SNF in K-Basins at Hanford. Hanford SNF could be eligible for repository disposal.
Draft EIS, Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center (DIRS 101729-DOE 1996, all)	HLW	Examines impacts of solidifying liquid HLW obtained from reprocessing commercial SNF. WVDP HLW could be eligible for repository disposal.
Final EIS, Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DIRS 101812-DOE 1996, all)	DOE SNF	Examines impacts of managing SNF from foreign research reactors in accordance with U.S. policy to reduce nuclear weapons proliferation. SNF from foreign research reactors stored at SRS and INEEL could be eligible for repository disposal.
Final EIS, Hanford Site Tank Waste Remediation System (DIRS 103214-DOE 1996, all)	HLW	Examines impacts of long-term management and disposal of Hanford tank waste, including HLW. Hanford HLW could be eligible for repository disposal.
Final EIS, Surplus Plutonium Disposition (DIRS 118979-DOE 1999, all)	Plutonium	Examines the alternatives for and impacts of disposition of surplus plutonium and of using mixed oxide fuel in six reactors. Ultimate disposition of the plutonium could involve repository disposal.
Draft EIS, Idaho High-Level Waste and Facilities Disposition (DIRS 155100-DOE 1999, all)	HLW	Examines impacts of treatment, storage, and disposal of INEEL HLW and facilities disposition. INEEL HLW could be eligible for repository disposal.
Final EIS, Savannah River Site Spent Nuclear Fuel Management (DIRS 156897-DOE 2000, all)	DOE SNF	Examines impact of several technologies for management of SNF at SRS, including placing these materials in forms suitable for ultimate disposition. Information from this EIS aids the study of packaging, transportation, and disposition of SNF.

Table 1-1. National Environmental Policy Act documents and Records of Decision related to the proposed Yucca Mountain Repository[a] (page 2 of 3).

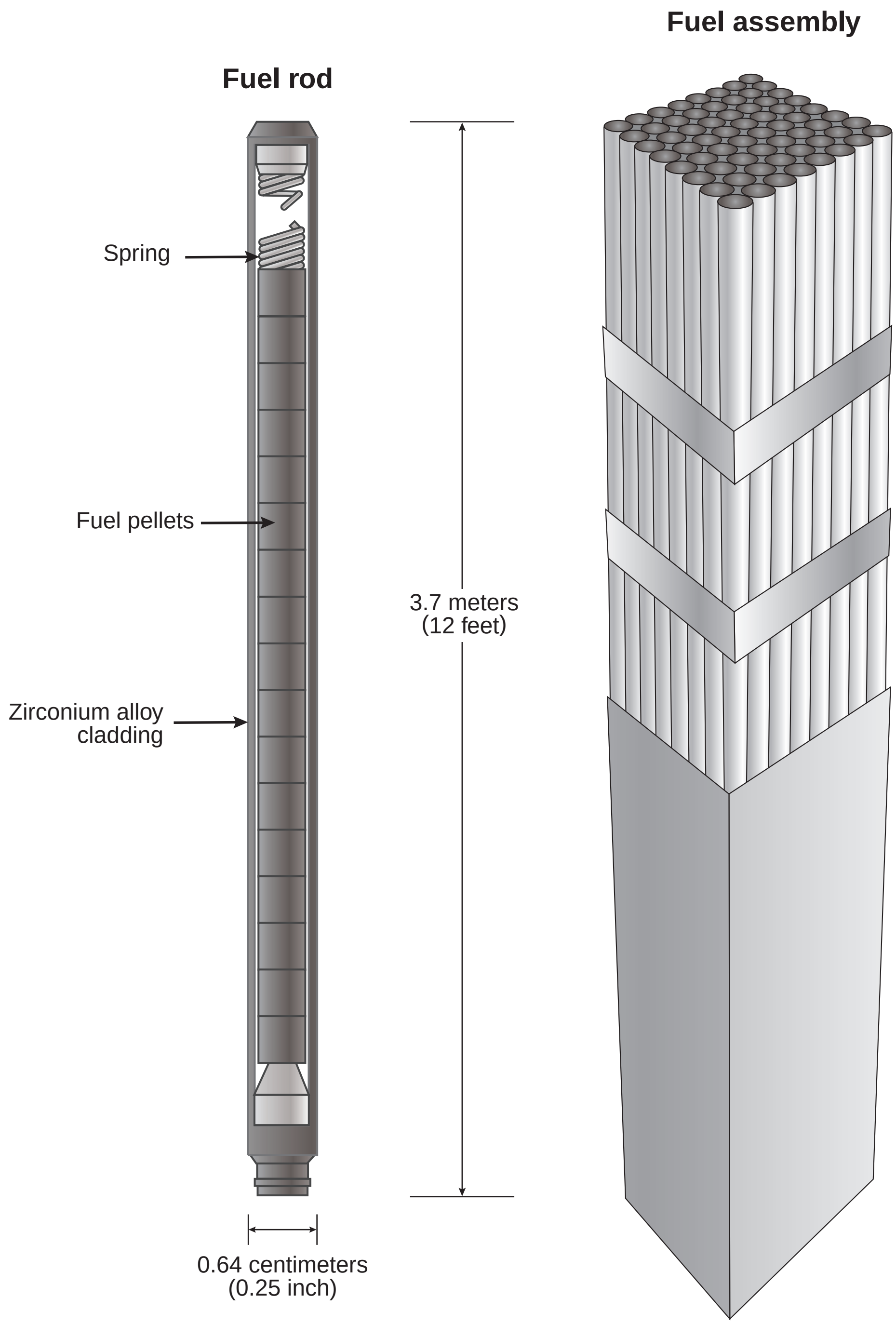
Document	Material type	Relationship to Yucca Mountain Repository EIS
Nuclear materials activities (continued)		
Record of Decision (62 *FR* 1095; January 8, 1997) and the Second Record of Decision (62 *FR* 23770; May 1, 1997) for a Container System for the Management of Naval Spent Nuclear Fuel Final EIS (DIRS 101941-USN 1996, all)	DOE SNF	Evaluates potential impacts of using alternative container systems for management of naval SNF following examination at INEEL. Naval SNF processed and stored at INEEL could be eligible for repository disposal. DOE used information from this EIS to estimate impacts from manufacture of disposal containers and shipping casks.
Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at INEEL (DIRS 103230-DOE 1999, all)	DOE SNF	Determines the use of a multipurpose canister or comparable system for the management of DOE SNF at INEEL that might be suitable for shipment using existing transportation casks.
Record of Decision for a Multi-Purpose Canister or Comparable System for Idaho National Engineering and Environmental Laboratory Spent Nuclear Fuel (64 *FR* 23825; May 4, 1999)	DOE SNF	Determines that multi-purpose canisters or comparable systems will be used for loading, storage, and transportation outside the State of Idaho of most DOE SNF located at INEEL.
Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report NUREG-1437 (DIRS 101899-NRC 1996, all; DIRS 101900-NRC 1996, all) and the Draft Supplement for the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Addendum 1 (DIRS 148185-NRC 1999, all)	Commercial SNF	Addresses the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, Nevada, and the impacts of transporting higher-burnup fuel.
Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel (65 *FR* 56565; September 19, 2000)	Sodium-bonded SNF	Determines that electrometallurgical processing will be used to treat sodium-bonded SNF other than SNF from Fermi-1.
Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Nuclear Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah (DIRS 152001-NRC 2000, all).	Commercial SNF	The proposal of Private Fuel Storage, L.L.C. (PFS) to construct and operate an independent spent fuel storage installation on the Reservation of the Skull Valley Band of Goshute Indians.
Programmatic examination of waste management		
Record of Decision (DIRS 103205-DOE 1995, all) for the Final Programmatic EIS, Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs (DIRS 101802-DOE 1995, all)	DOE SNF	Examines programmatic impacts of storage of DOE SNF that could be eligible for repository disposal. In the associated ROD, DOE decided where DOE SNF would be managed.
Final Programmatic EIS, Storage and Disposition of Weapons-Usable Fissile Materials (DIRS 103215-DOE 1996, all)	DOE SNF and HLW	Examines impacts of long-term storage of plutonium and highly enriched uranium at several DOE sites. Spent mixed-oxide fuel and immobilized plutonium could be eligible for repository disposal.

Table 1-1. National Environmental Policy Act documents and Records of Decision related to the proposed Yucca Mountain Repository[a] (page 3 of 3).

Document	Material type	Relationship to Yucca Mountain Repository EIS
Programmatic examination of waste management (continued)		
Final Programmatic EIS, Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DIRS 101816-DOE 1997, all)	HLW	Examines impacts of managing five types of waste at DOE sites. Examines storage of HLW canisters and transportation of HLW canisters between DOE sites and Yucca Mountain.
Final EIS, Nevada Test Site and Off-Site Locations in the State of Nevada (DIRS 101811-DOE 1996, all)		Examines potential impacts of future mission activities at NTS. DOE used information from NTS EIS for Yucca Mountain site description and environmental impacts of NTS waste management activities. Cumulative impact analysis included activities analyzed in NTS EIS.
Regional description and cumulative impact information		
Final EIS, Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station Fallon, Nevada (DIRS 148199-USN 1998, all)		Examines impacts of land withdrawal around Naval Air Station Fallon. Repository EIS analysis of cumulative impacts considered proposed actions at Naval Air Station Fallon.
Legislative EIS for Nellis Air Force Range Renewal (DIRS 103472-USAF 1999, all)		Examines impacts of renewal of land withdrawal for Nellis Air Force Range. Yucca Mountain site is partly on range, and Repository EIS considers proposed actions at Nellis in its cumulative impacts analysis.
Proposed Caliente Management Framework Plan Amendment and FEIS for the Management of Desert Tortoise Habitat (DIRS 103080-BLM 1999, all)		Examines the implementation of BLM management goals and actions for the administration of the desert tortoise habitat in Lincoln County, Nevada.
Final EIS for the Cortez Pipeline Gold Deposit (DIRS 103078-BLM 1996, all)		Examines potential for impacts from mining-related activities at a location in north central Nevada.
EA, Pipeline Infiltration Project (DIRS 103081-BLM 1999, all)		Examines potential for impacts from mining-related activities at a location in north central Nevada.
Final Legislative Environmental Impact Statement, Timbisha Shoshone Homeland (DIRS 154121-DOI 2000, all)		Examines the potential for impacts from creating a Timbisha Shoshone Tribal reservation in and around Death Valley National Park.
Draft Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials (DIRS 156910-DOE 2001, all)		Evaluates the environmental impacts associated with relocating the TA-18 capabilities and materials (presently located at Los Alamos) to each of four alternative sites, including NTS.

a. Abbreviations: BLM = Bureau of Land Management; DOE = U.S. Department of Energy; DOI = Department of the Interior; DWPF = Defense Waste Processing Facility; EA = environmental assessment; EIS = environmental impact statement; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory; NTS = Nevada Test Site; ROD = Record of Decision; SNF = spent nuclear fuel; SRS = Savannah River Site; WVDP = West Valley Demonstration Project.

Figure 1-1. Locations of commercial and DOE sites and Yucca Mountain.



Note: Design and dimensions can vary among types of fuel rods.

Source: Modified from DIRS 101802-DOE (1995, p. 1-3).

Figure 1-2. Typical commercial nuclear fuel assembly and rod.

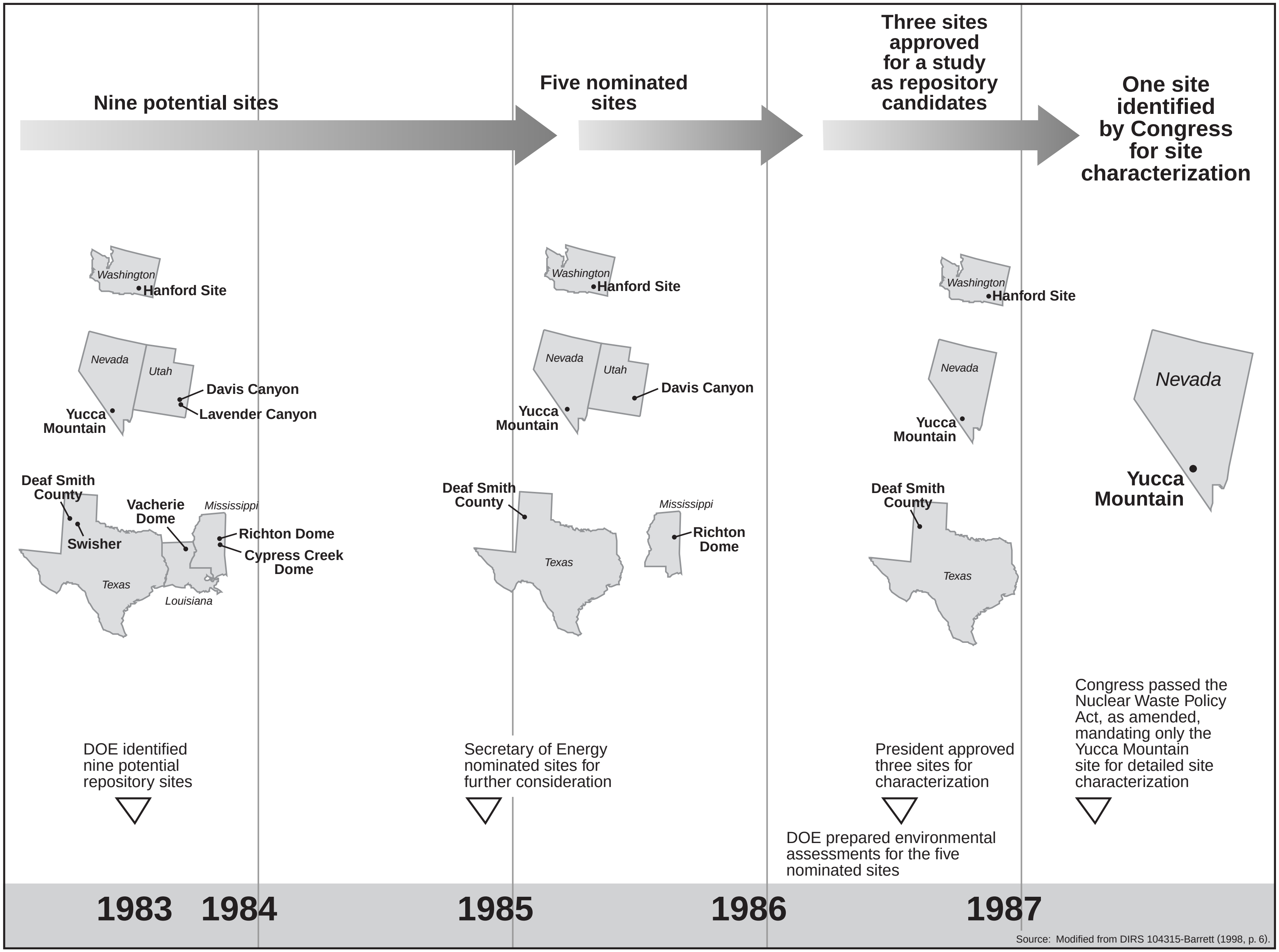
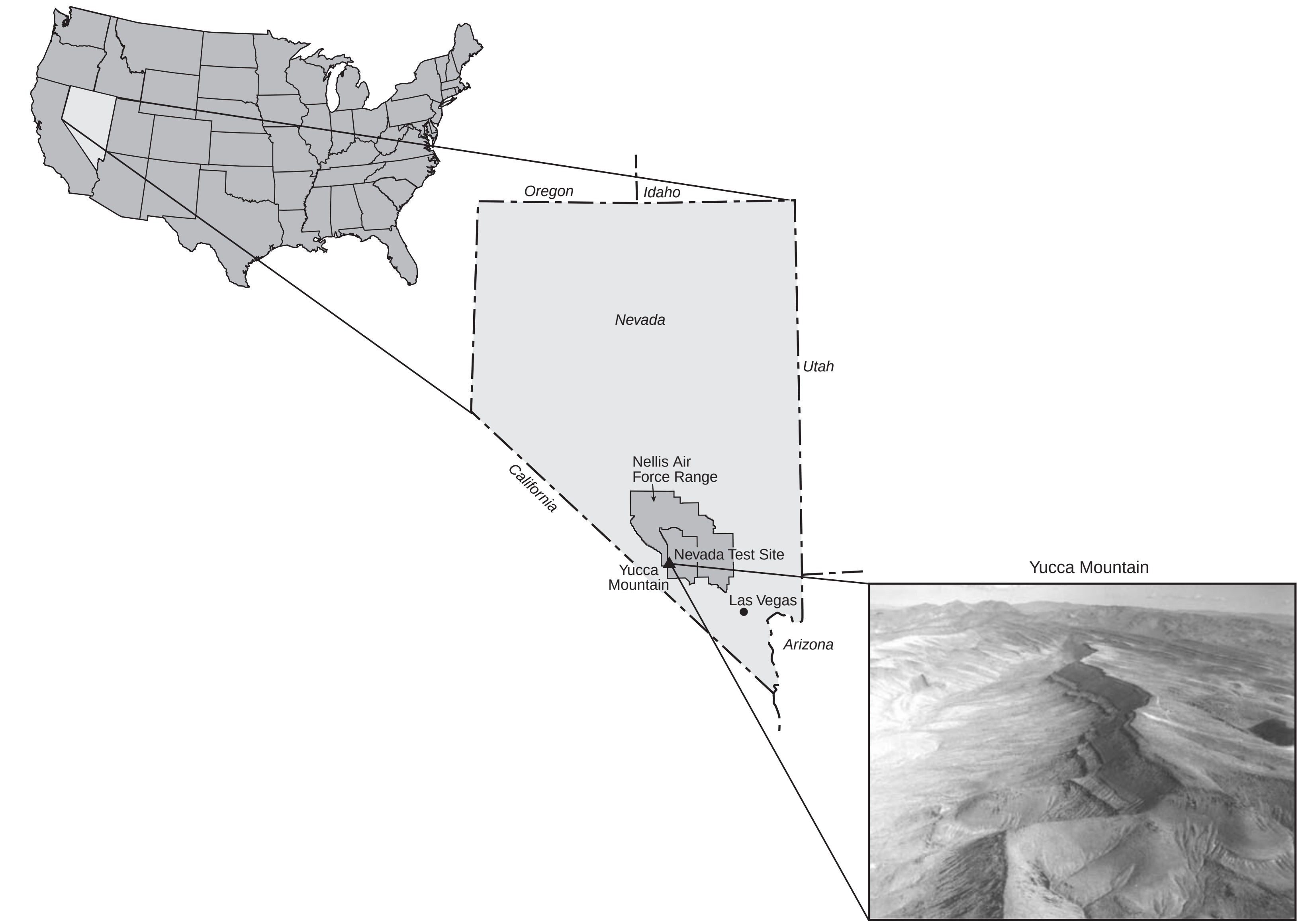


Figure 1-4. Events leading to selection of Yucca Mountain for study.



Source: Modified from DIRS 101779-DOE (1998, Overview, pp. 10 and 11).

Figure 1-5. Yucca Mountain location.

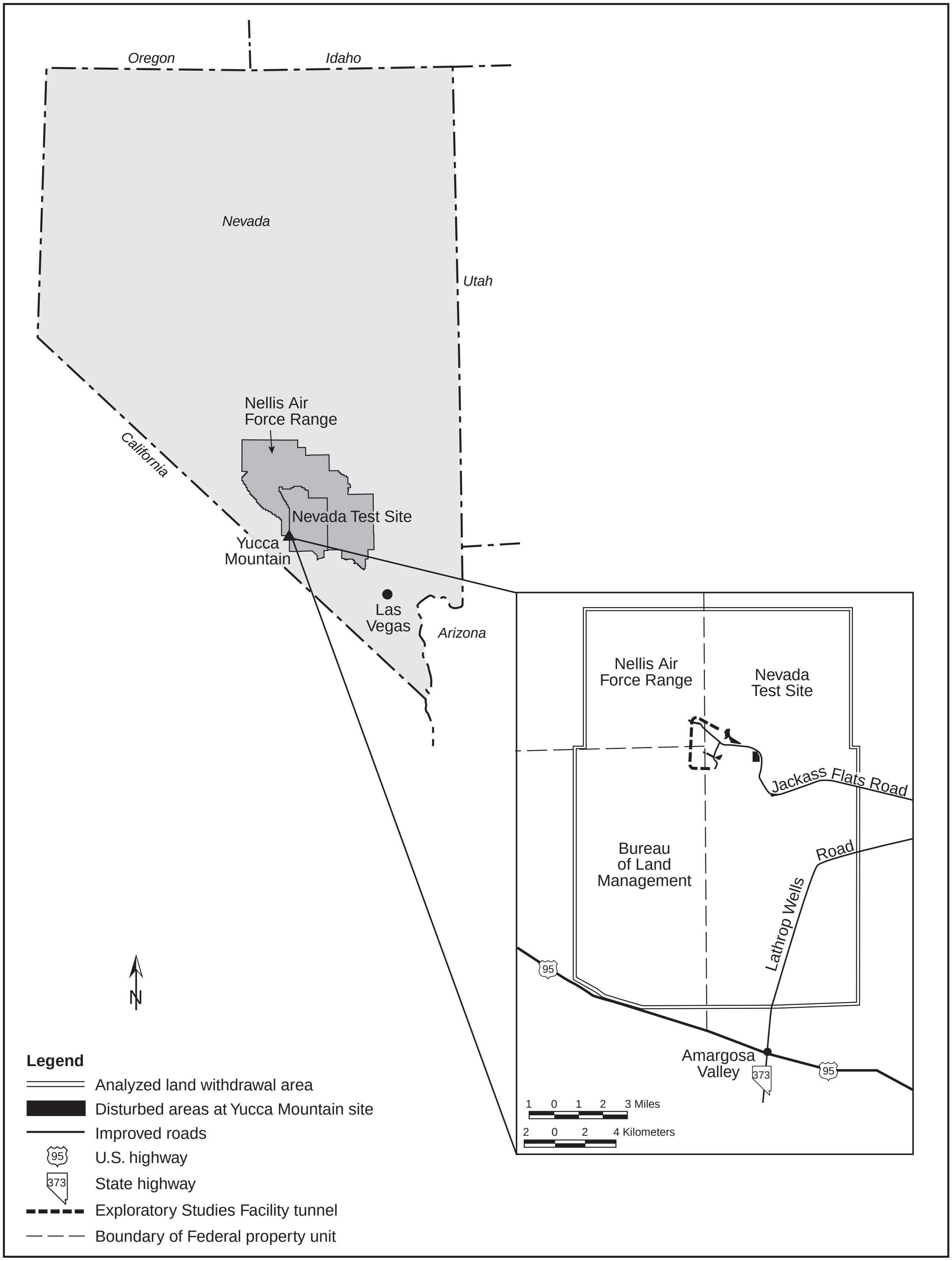


Figure 1-6. Land withdrawal area used for analytical purposes.

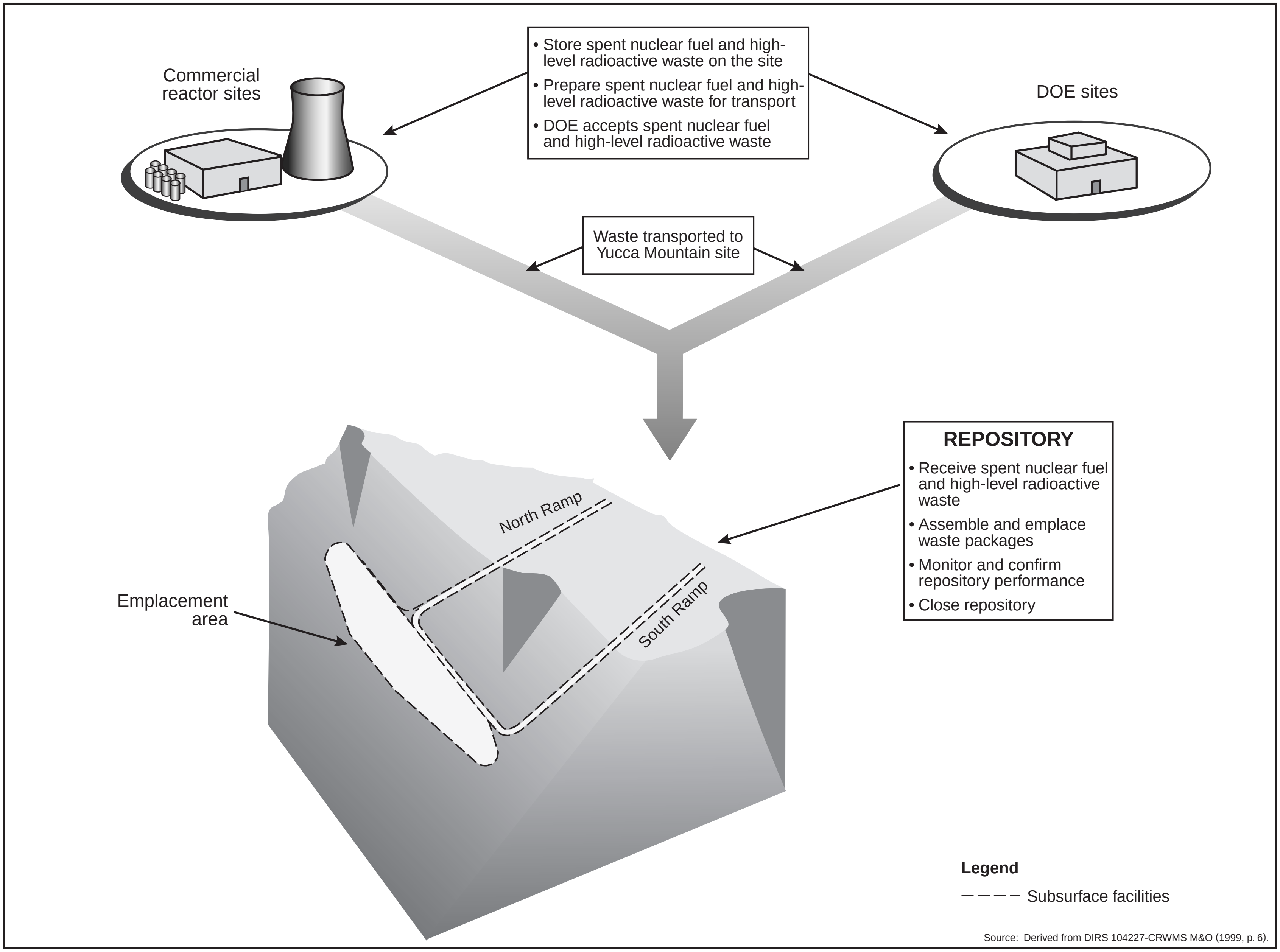


Figure 1-7. Spent nuclear fuel and high-level radioactive waste temporary storage, transportation, and disposal.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

102043 AIWS 1998 — AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.

104315 Barrett 1998 — Barrett, L. 1998. *Program Briefing for the U.S. Chamber of Commerce Energy and Natural Resources Committee, November 9, 1998.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19990526.0026.

103078 BLM 1996 — BLM (Bureau of Land Management) 1996. *Cortez Pipeline Gold Deposit: Final Environmental Impact Statement - Volume I.* Battle Mountain, Nevada: Bureau of Land Management. TIC: 242970.

103080 BLM 1999 — BLM (Bureau of Land Management) 1999. *Proposed Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat.* Ely, Nevada: U.S. Bureau of Land Management. TIC: 244133.

103081 BLM 1999 — BLM (Bureau of Land Management) 1999. *Cortez Gold Mines, Inc. Pipeline Infiltration Project.* Environmental Assessment NV063-EA98-062. Battle Mountain, Nevada: Bureau of Land Management. TIC: 243547.

154659 BSC 2001 — BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

155950 BSC 2001 — BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010801.0404; MOL.20010712.0062; MOL.20010815.0001.

157307 BSC 2001 — BSC (Bechtel SAIC Company) 2001. *Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation.* REV 00 ICN 02. Las Vegas, Nevada: Bechtel SAIC Co., LLC. ACC: MOL.20011213.0056.

103099	Buqo 1999	Buqo, T.S. 1999. *Nye County Perspective: Potential Impacts Associated With the Long-Term Presence of a Nuclear Repository at Yucca Mountain, Nye County, Nevada.* Pahrump, Nevada: Nye County Nuclear Waste Repository Office. TIC: 244065.
104227	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1999. *Reference Design Description for a Geologic Repository.* B00000000-01717-5707-00002 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990301.0225. In the Draft EIS, this reference was cited as DOE 1999a in Chapter 12.
104832	DOE 1980	DOE (U.S. Department of Energy) 1980. *Final Environmental Impact Statement Management of Commercially Generated Radioactive Waste.* DOE/EIS-0046F. Three volumes. Washington, D.C.: U.S. Department of Energy, Office of Nuclear Waste Management. ACC: HQZ.19870302.0183; HQZ.19870302.0184; HQZ.19870302.0185.
100136	DOE 1986	DOE (U.S. Department of Energy) 1986. *Environmental Assessment Yucca Mountain Site, Nevada Research and Development Area, Nevada.* DOE/RW-0073. Three volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQZ.19870302.0332.
100282	DOE 1988	DOE (U.S. Department of Energy) 1988. *Site Characterization Plan Yucca Mountain Site, Nevada Research and Development Area, Nevada.* DOE/RW-0199. Nine volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.19981201.0002.
103191	DOE 1994	DOE (U.S. Department of Energy) 1994. *Final Supplemental Environmental Impact Statement, Defense Waste Processing Facility.* DOE/EIS-0082-S. Aiken, South Carolina: U.S. Department of Energy. TIC: 243608.
101802	DOE 1995	DOE (U.S. Department of Energy) 1995. *Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement.* DOE/EIS-0203-F. Idaho Falls, Idaho: U.S. Department of Energy, Idaho Operations Office. TIC: 216020.
103205	DOE 1995	DOE (U.S. Department of Energy) 1995. *Record of Decision – Department of Energy Programmatic Spent Nuclear Fuel Management and the Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs.* Idaho Falls, Idaho: U.S. Department of Energy. TIC: 243787.

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103209 DOE 1995 DOE (U.S. Department of Energy) 1995. *Final Environmental Impact Statement, Interim Management of Nuclear Materials, Savannah River Site, Aiken, South Carolina.* DOE/EIS-0220. Aiken, South Carolina: U.S. Department of Energy. TIC: 243411.

101729 DOE 1996 DOE (U.S. Department of Energy) 1996. *Draft Environmental Impact Statement for Completion of the West Valley Demonstration Project and Closure or Long-Term Management of Facilities at the Western New York Nuclear Service Center.* DOE/EIS-0226-D. Two volumes. Washington, D.C.: U.S. Department of Energy. TIC: 223997.

101811 DOE 1996 DOE (U.S. Department of Energy) 1996. *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada.* DOE/EIS 0243. Las Vegas, Nevada: U.S. Department of Energy, Nevada Operations Office. TIC: 239895.

101812 DOE 1996 DOE (U.S. Department of Energy) 1996. *Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel.* DOE/EIS-0218F. Washington, D.C.: U.S. Department of Energy. TIC: 223998.

103213 DOE 1996 DOE (U.S. Department of Energy) 1996. *Addendum (Final Environmental Impact Statement), Management of Spent Nuclear Fuel from the K-Basins at the Hanford Site, Richland, Washington.* DOE/EIS-0245F. Richland, Washington: U.S. Department of Energy. TIC: 243958.

103214 DOE 1996 DOE (U.S. Department of Energy) 1996. *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement.* DOE/EIS-0189. Richland, Washington: U.S. Department of Energy. TIC: 226909.

103215 DOE 1996 DOE (U.S. Department of Energy) 1996. *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement.* DOE/EIS-0229. Summary and four volumes. Washington, D.C.: U.S. Department of Energy. TIC: 243897.

101816 DOE 1997 DOE (U.S. Department of Energy) 1997. *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste.* DOE/EIS-0200-F. Summary and five volumes. Washington, D.C.: U.S. Department of Energy, Office of Environmental Management. TIC: 232988.

101779	DOE 1998	DOE (U.S. Department of Energy) 1998. *Viability Assessment of a Repository at Yucca Mountain.* DOE/RW-0508. Overview and five volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981007.0027; MOL.19981007.0028; MOL.19981007.0029; MOL.19981007.0030; MOL.19981007.0031; MOL.19981007.0032.
103230	DOE 1999	DOE (U.S. Department of Energy) 1999. *Supplement Analysis for a Container System for the Management of DOE Spent Nuclear Fuel Located at the INEEL.* DOE/ID-10636. Idaho Falls, Idaho: U.S. Department of Energy. TIC: 244067.
118979	DOE 1999	DOE (U.S. Department of Energy) 1999. *Surplus Plutonium Disposition Final Environmental Impact Statement.* DOE/EIS-0283. Washington, D.C.: U.S. Department of Energy, Office of Fissile Materials Disposition. TIC: 246385.
155100	DOE 1999	DOE (U.S. Department of Energy) 1999. *Idaho High-Level Waste and Facilities Disposition Draft Environmental Impact Statement.* DOE/ EIS-0287D. Idaho Falls, Idaho: U.S. Department of Energy, Idaho Operations Office. ACC: MOL.20001030.0151.
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155734	DOE 2001	DOE (U.S. Department of Energy) 2001. *Yucca Mountain Preliminary Site Suitability Evaluation.* DOE/RW-0540. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20011101.0082.
156910	DOE 2001	DOE (U.S. Department of Energy) 2001. *Draft Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory - Summary.* DOE/EIS-319D. Washington, D.C.: United States Department of Energy: National Nuclear Security Administration.
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103414 NRC 1976 NRC (U.S. Nuclear Regulatory Commission) 1976. *Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors.* NUREG-0002. Executive Summary and five volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 243889.

101899 NRC 1996 NRC (U.S. Nuclear Regulatory Commission) 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report.* NUREG-1437, Vol. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233963.

101900 NRC 1996 NRC (U.S. Nuclear Regulatory Commission) 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Appendices, Final Report.* NUREG-1437, Vol. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233962.

148185 NRC 1999 NRC (U.S. Nuclear Regulatory Commission) 1999. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Section 6.3 - Transportation, Table 9.1 Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants, Draft Report for Comment.* NUREG-1437, Vol. 1, Addendum 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 244062.

152001 NRC 2000 NRC (U.S. Nuclear Regulatory Commission) 2000. *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah.* NUREG-1714. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. ACC: MOL.20000828.0030.

103472 USAF 1999 USAF (U.S. Air Force) 1999. *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement.* Washington, D.C.: U.S. Department of the Air Force. TIC: 243264.

101941 USN 1996 USN (U.S. Department of the Navy) 1996. *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel.* DOE/EIS-0251. Washington, D.C.: U.S. Department of Energy. TIC: 227671.

148199 USN 1998 USN (U.S. Department of the Navy) 1998. *Final Environmental Impact Statement (FEIS) for the Withdrawal of Public Lands for Range Safety and Training Purposes at Naval Air Station (NAS) Fallon, Nevada.* Fallon, Nevada: U.S. Department of the Navy. TIC: 243879.

104630 YMP 1997 YMP (Yucca Mountain Site Characterization Project) 1997. *Summary of Public Scoping Comments Related to the Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19970731.0515. In the Draft EIS, this reference was cited as DOE 1997a in Chapter 12.

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2. PROPOSED ACTION AND NO-ACTION ALTERNATIVE

Under the Proposed Action, the U.S. Department of Energy (DOE) would construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain (see Section 2.1). The Proposed Action includes transportation of spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the Yucca Mountain site (see Figure 2-1).

Under the No-Action Alternative (see Section 2.2), DOE would end site characterization activities at Yucca Mountain, and the commercial and DOE sites would continue to manage their spent nuclear fuel and high-level radioactive waste (see Figure 2-1). The No-Action Alternative assumes that spent nuclear fuel and high-level radioactive waste would be treated and packaged as necessary for its safe *onsite* management. DOE does not intend to represent the No-Action Alternative as a viable long-term solution but rather to use it as a basis against which the Proposed Action can be evaluated.

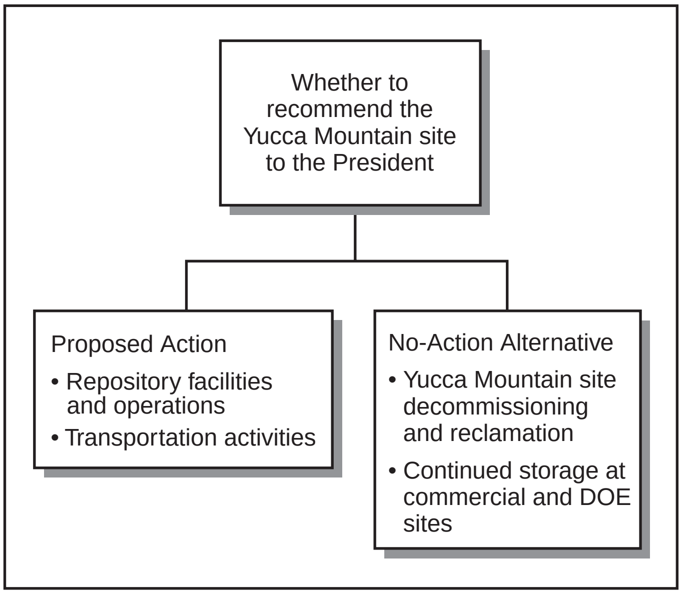

Figure 2-1. General activity areas evaluated under the Proposed Action and No-Action Alternative.

Section 2.3 discusses the alternatives that DOE considered but eliminated from detailed study in this environmental impact statement (EIS). Section 2.4 summarizes findings from the EIS and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative. Section 2.5 addresses the collection of information and analyses performed for the EIS. Section 2.6 identifies the preferred alternative.

DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the Nuclear Waste Policy Act, as amended (NWPA, 42 U.S.C 10101 *et. seq.*), in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

As part of the Proposed Action, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations, associated routes for heavy-haul trucks, and alternative corridors for a branch rail line.

DOE believes that the EIS provides the information necessary to make decisions regarding the basic approaches to transportation (for example, rail or truck shipments), as well as the choice among alternative rail corridors in Nevada. However, follow-on implementing decisions, such as selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, the Department has not identified a preference for a specific rail corridor in Nevada. If the Yucca Mountain site was recommended and approved, DOE would identify such a preference in consultation with affected stakeholders, particularly the State of Nevada. In this case, DOE would announce its preferred corridor in a *Federal Register* notice, and would publish its decision to select a corridor in a Record of Decision no sooner than 30 days after the announcement of a preference.

2.1 Proposed Action

DOE proposes to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain for the disposal of spent nuclear fuel and high-level radioactive waste. In its simplest terms, the proposed repository would be a large underground excavation with a network of *drifts* (tunnels) that DOE would use for spent nuclear fuel and high-level radioactive waste emplacement. About 600 square kilometers (230 square miles or 150,000 acres) of land in Nye County, Nevada, could be permanently withdrawn from public access for repository use. The proposed location of the repository is shown in Figure 2-2. DOE would dispose of spent nuclear fuel and high-level radioactive waste in the repository using the inherent, natural geologic features of the mountain and engineered (manmade) barriers to help ensure the long-term isolation of the spent nuclear fuel and high-level radioactive waste from the human environment. DOE would build the repository emplacement drifts inside Yucca Mountain at least 200 meters (660 feet) below the surface and at least 160 meters (530 feet) above the present-day *water table* (DIRS 154554-BSC 2001, pp. 28 and 29).

Under the Proposed Action, DOE would permanently place approximately 11,000 (DIRS 152010-CRWMS M&O 2000, p. 14) to 17,000 waste packages containing no more than 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain. Of the 70,000 MTHM to be emplaced in the repository, 63,000 MTHM would be spent nuclear fuel assemblies from boiling-water and *pressurized-water reactors* (Figure 2-3) that DOE would ship from commercial nuclear sites to the repository. The remaining 7,000 MTHM would consist of about 2,333 MTHM of DOE spent nuclear fuel and 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste (see Figure 2-3) that the Department would ship to the repository from its facilities. The 70,000-MTHM inventory would include surplus weapons-usable plutonium as spent mixed-oxide fuel or immobilized plutonium. Appendix A contains additional information on the inventory and characteristics of spent nuclear fuel, high-level radioactive waste, and other materials that DOE could emplace in the proposed repository. For this EIS, a connected action includes the offsite manufacturing of the containers that DOE would use for the transport and disposal of spent nuclear fuel and high-level radioactive waste and the specialized titanium drip shields and corrosion-resistant emplacement pallets that DOE could install over and under, respectively, the waste packages to improve performance and to reduce *uncertainty* about the long-term performance of the repository.

DEFINITION OF METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

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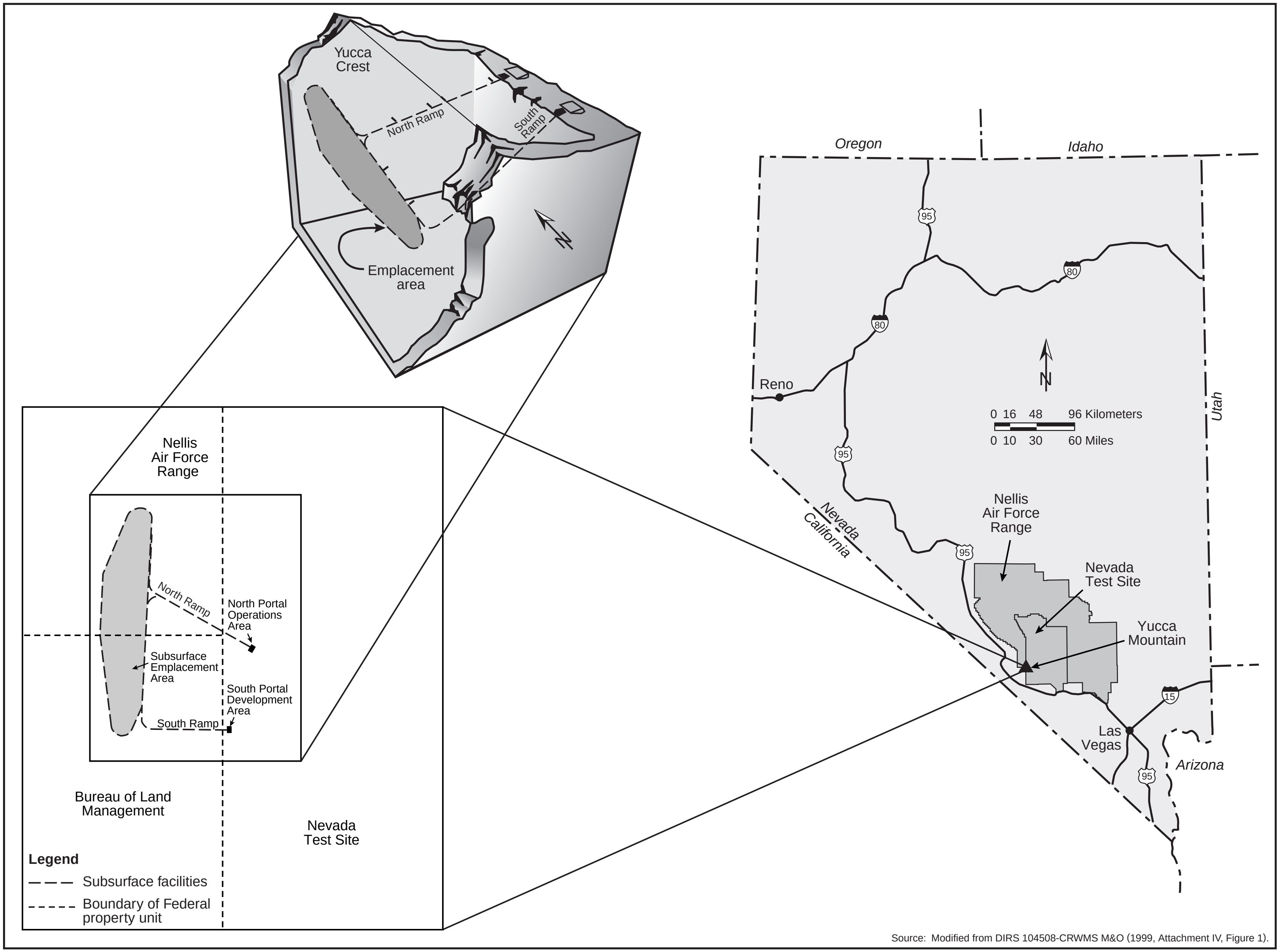

Source: Modified from DIRS 104508-CRWMS M&O (1999, Attachment IV, Figure 1).

Figure 2-2. Diagram and location of the proposed repository at Yucca Mountain.

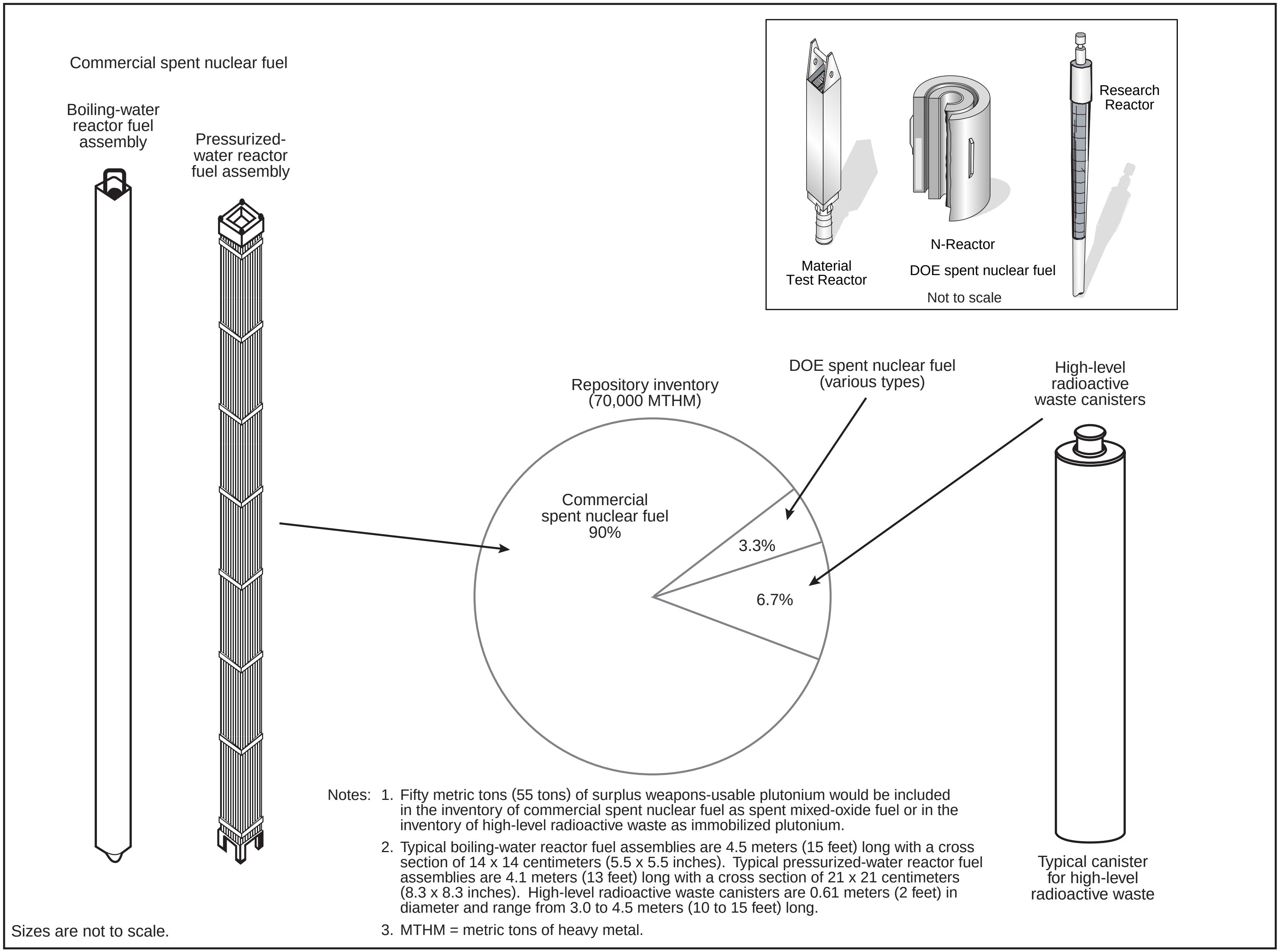

Figure 2-3. Sources of spent nuclear fuel and high-level radioactive waste proposed for disposal at the Yucca Mountain Repository.

Figure 2-4 is an overview of components or activities associated with the Proposed Action. The implementing alternatives and scenarios analyzed in this EIS, as described in Section 2.1.1, represent the potential range of variables associated with implementing the Proposed Action that could affect environmental impacts. The Proposed Action would require surface and subsurface facilities and operations for the receipt, packaging, possible surface *aging*, and emplacement of spent nuclear fuel and high-level radioactive waste (see Section 2.1.2) and transportation of these materials to the repository (see Section 2.1.3). Section 2.1.5 summarizes the estimated cost of the Proposed Action. Chapters 4, 5, and 6 evaluate potential environmental impacts from the Proposed Action. As part of the process to develop implementing concepts, mitigation techniques have been designed into the Proposed Action through the use of best engineering and management practices, as applicable.

The Proposed Action would use two types of institutional controls—active and passive. Active institutional controls (monitored and enforced limitations on site access; inspection and *maintenance* of waste packages, facilities, equipment, etc.) would be used through closure. Passive institutional controls (markers, engineered barriers, etc., that are not monitored or maintained) would be put in place during closure and used to minimize inadvertent exposures to members of the public in the future.

2.1.1 OVERVIEW OF IMPLEMENTING ALTERNATIVES AND SCENARIOS

This EIS describes and evaluates the current preliminary design concept for repository surface facilities, subsurface facilities, and disposal containers (waste packages), and the current plans for the construction, operation and monitoring, and closure of the repository. DOE recognizes that plans for the repository would continue to evolve during the development of the final repository design and as a result of the U.S. Nuclear Regulatory Commission licensing review of the repository. While the design continues to evolve, it is based on decades of similar experience in mining operations and the management of spent nuclear fuel and other radioactive materials, as well as the ongoing site characterization and *performance confirmation* activities and results. In addition, decisions on how spent nuclear fuel and high-level radioactive waste would be shipped to the repository (for example, truck or rail) and how spent nuclear fuel would be packaged (*uncanistered* or in disposable or dual-purpose canisters) would be part of future transportation planning efforts.

DISPOSAL CONTAINERS AND WASTE PACKAGES

A *disposal container* is the vessel consisting of the barrier materials and internal components in which the spent nuclear fuel and high-level radioactive waste would be placed. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

For these reasons, DOE developed implementing alternatives and analytical scenarios to bound the environmental impacts likely to result from the Proposed Action in the EIS (see Figure 2-5). The Department selected the implementing alternatives and scenarios to accommodate and maintain flexibility for potential future revisions to the design and operation of the repository. Because of uncertainties, DOE selected implementing alternatives and scenarios that incorporate conservative assumptions that tend to overstate the risks to address those uncertainties.

The following paragraphs describe the packaging scenarios, repository operating modes, national transportation scenarios, Nevada transportation scenarios, and implementing rail and intermodal alternatives evaluated in the EIS.

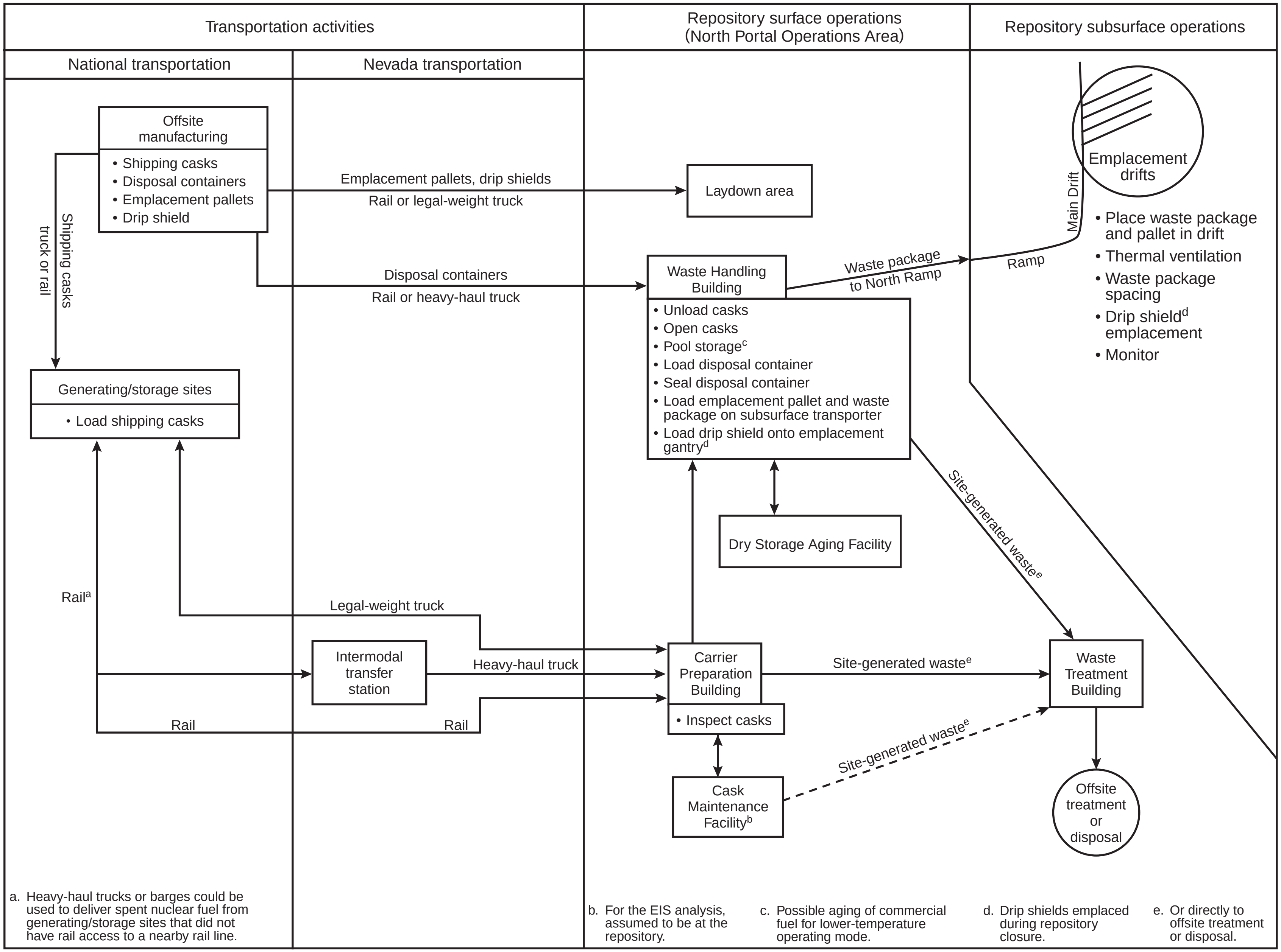

Figure 2-4. Overview flowchart of the Proposed Action.

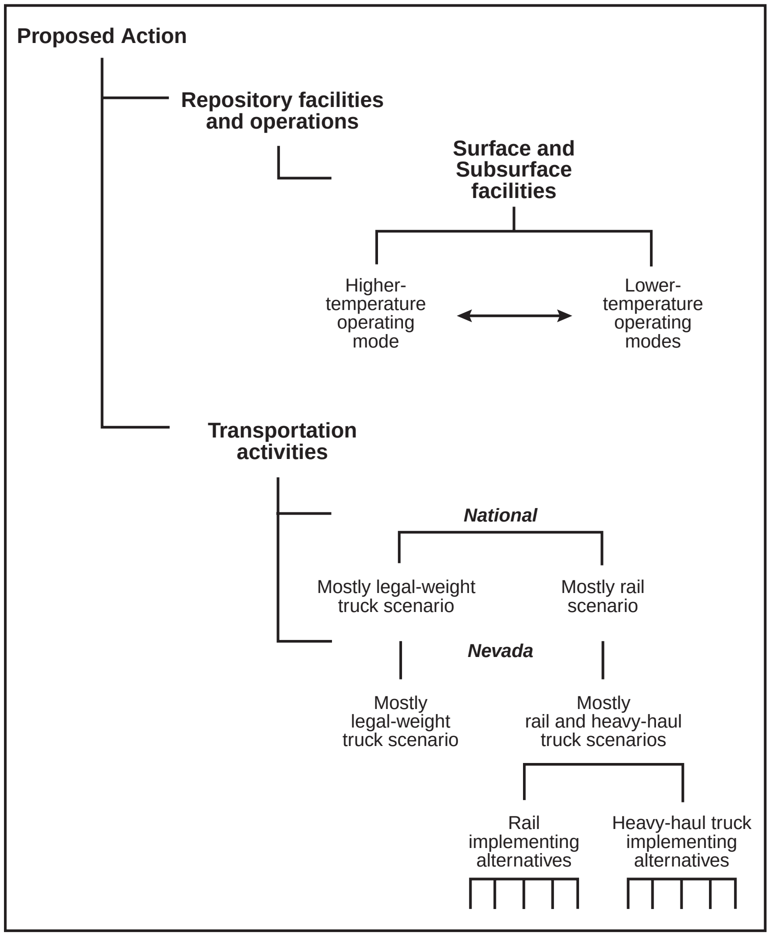

Figure 2-5. Analytical scenarios and implementing alternatives associated with the Proposed Action.

2.1.1.1 Packaging Scenarios

DOE operations at repository surface facilities would differ depending on how the spent nuclear fuel in shipping casks was packaged. Commercial spent nuclear fuel could be received either uncanistered or in disposable or dual-purpose canisters.

The EIS assumes that DOE spent nuclear fuel and high-level radioactive waste would be shipped to the repository in *disposable canisters*. In addition, it evaluates the following packaging scenarios for commercial spent nuclear fuel to cover the potential range of environmental impacts from repository surface facility construction and operation:

- A mostly uncanistered fuel scenario
- A mostly canistered fuel scenario

For this Final EIS, DOE simplified the presentation of the packaging scenarios that were analyzed in the Draft EIS by analyzing only one bounding packaging scenario (the Draft EIS considered both mostly canistered and uncanistered scenarios). DOE was able to simplify the presentation of impacts in the Final EIS because the Draft EIS analysis demonstrated that the mostly uncanistered fuel packaging scenario bounded the analysis in all cases with the exception of (1) the empty dual-purpose canisters that some commercial sites could use that would require disposal or recycling, and (2) some attributes of offsite manufacturing of the disposable canister. The presentation of potential impacts in Chapter 4 of this Final

DEFINITIONS OF PACKAGING TERMS

Shipping cask: A vessel that meets applicable regulatory requirements for shipping spent nuclear fuel or high-level radioactive waste.

Dual-purpose canister: A metal vessel suitable for storing (in a storage facility) and shipping (in a shipping cask) commercial spent nuclear fuel assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The spent nuclear fuel assemblies would be removed from the canister and placed in a disposal container or in the fuel pool to accommodate blending. The opened canister would be recycled or disposed of offsite as low-level radioactive waste.

Disposable canister: A metal vessel for commercial or DOE spent nuclear fuel assemblies or solidified high-level radioactive waste suitable for storage, shipping, and disposal. At the repository, the disposable canister would be removed from the shipping cask and placed directly in a disposal container. The disposable canister is sometimes referred to as a multi-purpose canister in discussions of repository design.

Uncanistered spent nuclear fuel: Commercial spent nuclear fuel placed directly into shipping casks. At the repository, spent nuclear fuel assemblies would be removed from the shipping cask and placed in a disposal container or in the fuel pool to accommodate blending.

Disposal container: A container for spent nuclear fuel and high-level radioactive waste consisting of the barrier materials and internal components. The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

Waste package: The filled, sealed, and tested disposal container that would be emplaced in the repository.

EIS primarily reports impacts associated with the mostly uncanistered scenario. Where the canistered scenario would result in greater impacts (that is, waste management and offsite manufacturing impacts), the greater impacts are provided. Therefore, the scenarios discussed in this Final EIS represent current design concepts and bound the impacts of any canister scenario, including the disposable canister scenario. DOE ultimately might select either scenario. For all scenarios, high-level radioactive waste and DOE spent nuclear fuel remain in the disposable canisters in which they were received for emplacement.

Table 2-1 summarizes these scenarios.

Table 2-1. Packaging scenarios (percentage based on number of shipments).

Material[a]	Mostly uncanistered fuel	Mostly canistered fuel
Commercial SNF	100% uncanistered fuel	About 80% dual-purpose canisters; about 20% uncanistered fuel
HLW	100% disposable canisters	100% disposable canisters
DOE SNF	100% disposable canisters	100% disposable canisters

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.

2.1.1.2 Repository Operating Modes

The heat generated by spent nuclear fuel and high-level radioactive waste could affect the long-term performance of the repository (that is, the ability of the engineered and natural barrier systems to isolate the emplaced waste from the human environment). Different repository operating modes would have a direct effect on internal and external waste package temperatures, thereby potentially affecting the corrosion rate and integrity of the waste packages.

Parameters associated with maximum repository temperatures (see Table 2-2) are central to defining the operating modes of the flexible design. The repository temperature would depend on factors related to the design and operation of the repository including, but not limited to, the age and *burnup* of the spent nuclear fuel at the time of emplacement, the spacing of the emplacement drifts and the waste packages in them, and the repository ventilation method and duration. The implementation of these design and operational parameters would affect the short-term environmental impacts of the repository.

Table 2-2. Summary of key underground design and operating parameters associated with repository operating modes analyzed in the EIS.

		Repository operating mode	
Parameter	Unit of measure	Higher-temperature[a]	Lower-temperature[b]
Linear thermal load	Kilowatts per meter	1.42	0.65 to 1[c]
Drift spacing	Meters[d]	81	81[e]
Areal mass load	MTHM[f] per acre	56	25 to 39
Waste package spacing	Meters	0.1	0.1 to 6.4[e]
Emplacement duration	Years	24	24 (50)[g]
Preclosure ventilation duration[h]	Years	100	149 to 324
Closure duration	Years	10	11 to 17
Ventilation rate (forced)	Cubic meters[i] per second in drift	15	15
External ventilation shafts (emplacement and development)	Number	7	9 to 17
Dependent parameter			
Underground area	Square kilometers	4.7	6.5 to 10.1
Total excavated repository volume[j]	Millions of cubic meters	4.4	5.7 to 8.8
Waste packages	Number (in thousands)	11 to 12	11 to 17

a. Source: DIRS 150941-CRWMS M&O (2000, all).
b. Sources: DIRS 152003-McKenzie (2000, all); DIRS 153849-DOE (2001, all).
c. If commercial SNF is aged, linear thermal loads will be lower.
d. To convert meters to feet, multiply by 3.2808.
e. Drift spacing and waste package spacing determine various areal mass loads.
f. MTHM = metric tons of heavy metal.
g. The lower-temperature repository operating mode analysis assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period for scenarios that used aging at the repository.
h. From start of emplacement to start of repository closure.
i. To convert cubic meters to cubic feet, multiply by 35.314.
j. Includes existing Exploratory Studies Facility volume of 420,000 cubic meters (15 million cubic feet).

The basis for the three thermal load scenarios in the Draft EIS was the amount of commercial spent nuclear fuel that DOE would emplace per unit area of the repository (areal mass loading). These scenarios included a relatively high emplacement density of commercial spent nuclear fuel (high thermal load – 85 MTHM per acre), a relatively low emplacement density (low thermal load – 25 MTHM per acre), and an emplacement density between the high and low thermal loads (intermediate thermal load – 60 MTHM per acre).

Rather than focusing on thermal loads, the flexible design focuses on controlling the temperature of the rock between the drifts, and on the surface of the waste package and drift walls. The flexible design uses a *linear thermal load* (heat output per unit length of the emplacement drift) and emplaces waste packages closer together than the Draft EIS design. Linear thermal load is expressed in terms of kilowatts per meter.

The design discussed in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DIRS 153849-DOE 2001, all) includes the ability to operate the repository in a range of modes that address higher and lower temperatures. *Higher-temperature* means that at least a portion of the emplacement drift rock wall would have a maximum temperature above the boiling point of water at the elevation of the repository [96°C (205°F)]. The *lower-temperature* operating mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85°C (185°F).

To construct the analytical basis for evaluation of repository impacts, DOE used widely accepted analytical tools, coupled with the best available information, and cautious but reasonable assumptions where uncertainties exist, to estimate potential environmental impacts. This included applying conservative assumptions to the set of reasonable operating scenarios identified in the Science and Engineering Report (DIRS 153849-DOE 2001, p. 2-24) to ensure that the EIS did not underestimate potential environmental impacts and to accommodate the greatest range of potential future actions.

DOE has established parameters for the range of potential repository operating modes and has identified these parameters and their ranges in Table 2-2. These operating modes provide the basis for evaluation of the environmental impacts described in Chapter 4. The key to ensuring that the range of potential impacts evaluated fully encompasses the impacts that could occur under any reasonable repository mode of operation requires a basic understanding of how the particular impacts relate to the various parameters, particularly those parameters that could be varied to achieve lower-temperature operation.

As shown in the Draft EIS and the Supplement to the Draft EIS, the short-term impacts (preclosure) would increase with the size of the repository emplacement area and surface facilities. The smallest repository and surface facilities are associated with the higher-temperature repository operating mode and therefore would result in the lowest short-term environmental impacts. As detailed in Section 2.1.1.2.2, the lower-temperature repository operating mode would be achieved by varying several of the design parameters independently or in combination, for differing effects. Design parameters include waste package loading, repository ventilation duration, and waste package spacing. In the analyses, DOE maximized each of these parameters in turn, and assumed reasonably conservative values for the other dependent parameters to evaluate the full range of potential environmental impacts. As an example, DOE considered a repository with the largest waste package spacing (6.4 meters), with and without the use of surface aging. The result was the largest repository emplacement area and surface facilities and therefore the highest potential impacts for some *environmental resource areas* (for example, land disturbance, nonradiological air quality, and water use). Conversely, when DOE assumed the long postemplacement ventilation period (up to 300 years), with and without the surface aging facility, the result was a repository that would be open for a longer period with higher potential for impacts to workers and release of naturally occurring radon from the open repository to the offsite public. DOE evaluated the reasonable combinations of these variable design parameters to establish the range of impacts reported in Chapter 4 and summarized in Section 2.4.

2.1.1.2.1 *Higher-Temperature Repository Operating Mode*

The higher-temperature repository operating mode would ensure that a portion of the rock between the drifts would have maximum temperatures below the boiling point of water [96°C (205°F)] (DIRS 153849-DOE 2001, Section 2.1.2) at the elevation of the emplacement horizon (see Figure 2-6). This would allow any water mobilized by the higher-temperature conditions in the drifts to drain between the drifts. The development of a localized boiling region around each emplacement drift, rather than a single boiling region encompassing all the emplacement drifts, would ensure that very little water would be able to accumulate above any emplacement drift. This would substantially decrease the likelihood of water penetrating the emplacement drifts by means of fast paths such as fractures. The higher-temperature operating mode is based on this heat management criterion to keep boiling temperatures from spreading

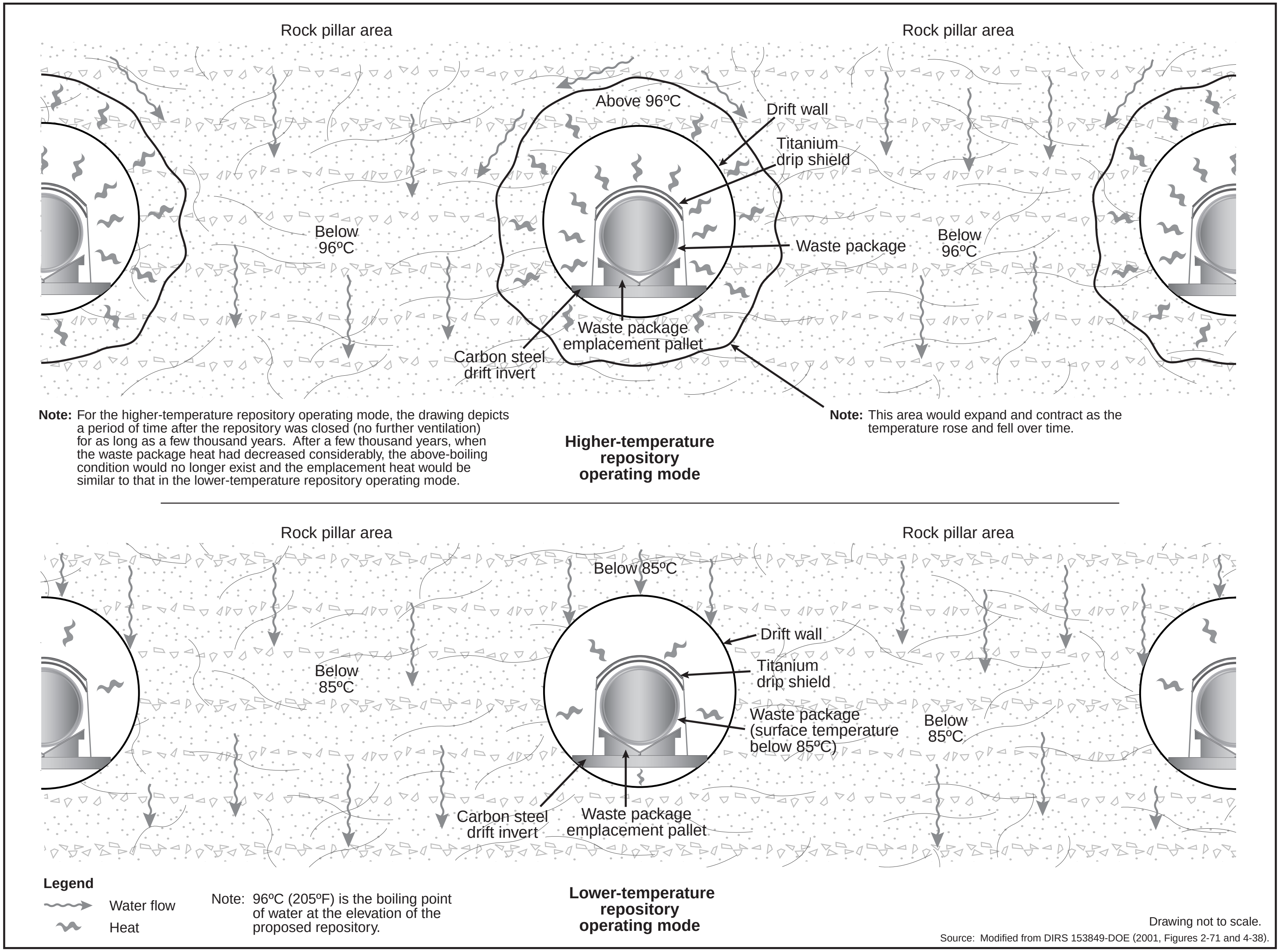

Figure 2-6. Artist's conception of water flow around emplacements for higher- and lower-temperature repository operating modes.

all the way through the rock between drifts after closure, while allowing repository closure as early as 50 years after the start of emplacement.

2.1.1.2.2 *Lower-Temperature Repository Operating Mode*

DOE could operate the repository in a lower-temperature mode by varying certain operational parameters. The lower-temperature operating mode range includes conditions under which the drift rock wall temperatures would be below the boiling point of water [96ºC (205ºF)] at the elevation of the repository, as well as conditions under which waste package average surface temperatures would not exceed 85ºC (185ºF) (see Figure 2-6).

DOE is considering the lower-temperature operating mode to reduce some of the uncertainties associated with assessing long-term repository performance. Lower temperatures might have less effect on rock properties and geochemistry, thereby reducing the complexities in modeling thermal effects. This, in turn, could reduce uncertainties in assessments of future repository performance. Lower in-drift temperatures could also reduce the potential for waste package corrosion.

The primary variables governing a lower waste package surface temperature and the thermal response of the surrounding rock would be the heat generation rate of the waste packages, the linear spacing of the waste packages in the emplacement drifts, and the rate and duration of ventilation after waste package emplacement in the drifts. Operational parameters that DOE could use (independently or in combination) to control repository temperatures (waste package, drift wall, and the overall repository) include (1) varying the waste package *thermal loading* to control the thermal output, (2) varying the duration of the preclosure ventilation period with 15-cubic-meter (530-cubic-foot)-per-second average drift ventilation, and (3) varying the distances between waste packages in the emplacement drifts (DIRS 153849-DOE 2001, Section 2.1.4). The operational parameters would work in combination to control the maximum waste package surface temperature and, thus, the heat transferred to the emplacement drift walls. DOE could use a combination of the three to maximize repository operational efficiency and achieve thermal objectives, as described below.

- *Waste Package Thermal Loading (including surface aging).* Commercial spent nuclear fuel would be the major contributor of heat in the repository. It would have a wide range of thermal outputs. The thermal output of the waste packages could be reduced, however, by varying waste package loading. Waste package thermal loading could be varied by (1) placing low-heat-output (older) fuel with high-heat-output (younger) fuel in the same waste package (fuel *blending*), (2) limiting the number of spent nuclear fuel assemblies to less than the waste package design capacity (derating), (3) using smaller waste packages, or (4) placing younger fuel in a surface aging area to allow its heat output to dissipate so it could meet thermal goals for later emplacement. Section 2.1.2.1.1.2 describes the fuel blending process further. Reducing the thermal output of the waste packages through any of these means would achieve lower waste package and drift wall temperatures. DOE would consider aging as much as two-thirds of the commercial spent nuclear fuel (DIRS 152007-Mattsson 2000, p. 2) during a 50-year period. Aging would require an extended emplacement period.

- *Drift Ventilation Duration.* During repository operations, forced-air (active) or natural (passive) ventilation of the loaded drifts would remove an appreciable part of the heat generated by the waste packages. DOE could reduce the amount of heat delivered to, and thus the maximum temperatures in, the host rock by extending the drift ventilation period with either active or passive ventilation. This could require an extended ventilation period of as long as 300 years after final emplacement to ensure that postclosure temperatures (waste package surface and drift wall) remained below specified goals (DIRS 153849-DOE 2001, Section 2.1.5.2, Table 2-2).

- *Distance Between Waste Packages.* The distance between waste packages in emplacement drifts is another operational variable that DOE could use to manage the thermal response of the repository. With waste packages spaced farther apart, the linear thermal load in each drift would decrease, delivering less heat per unit length of the emplacement drift. Implementing an increase in average waste package spacing would require more emplacement drifts and potentially additional subsurface *infrastructure* than the higher-temperature repository operating mode. Under the lower-temperature repository operating mode, waste package spacing could vary from 0.1 meter (0.33 foot) (DIRS 153849-DOE 2001, Section 2.1.2.2) to 6.4 meters (21 feet) (DIRS 152003-McKenzie 2000, Option 1, p. 2).

These three operational parameters are interrelated; that is, they would work together to achieve the desired result. For example, a combination of 2.1-meter (6.9-foot) waste package spacing, surface aging of commercial spent nuclear fuel, and 125 years of forced-air ventilation (from the start of emplacement) would be adequate to achieve the repository lower-temperature thermal objectives. Another example would be a combination of 2-meter (6.6-foot) waste package spacing, no surface aging, and 75 years of forced-air ventilation (from the start of emplacement) followed by 250 years of *natural ventilation* (DIRS 153849-DOE 2001, Section 2.1.5.2, Table 2-2).

2.1.1.3 National Transportation Scenarios

The national transportation scenarios evaluated in this EIS encompass the transportation options or modes (legal-weight truck and rail) that are practical for DOE to use to ship spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site. DOE would use both legal-weight truck and rail transportation, and would determine the number of shipments by either mode as part of future transportation planning efforts. Therefore, the EIS evaluates two national transportation scenarios (mostly legal-weight truck and mostly rail) that cover the possible range of transportation impacts to human health and the environment.

TERMS ASSOCIATED WITH TRANSPORTATION

Legal-weight trucks have a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), which is the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be in compliance with Federal and state regulations.

An **intermodal transfer station** is a facility for transferring freight from one transportation mode to another (for example, from railcar to truck). In this EIS, intermodal transfer station refers to a facility DOE would use to transfer rail shipping casks containing spent nuclear fuel or high-level radioactive waste from railcars to heavy-haul trucks, and to transfer empty rail shipping casks from heavy-haul trucks to railcars.

Heavy-haul trucks are overweight, overdimension vehicles that must have permits from state highway authorities to use public highways. In this EIS, heavy-haul trucks refers to vehicles DOE would use on public highways to move spent nuclear fuel or high-level radioactive waste shipping casks designed for a railcar.

2.1.1.4 Nevada Transportation Scenarios and Rail and Intermodal Implementing Alternatives

The transportation of spent nuclear fuel and high-level radioactive waste to the proposed repository would affect the states through which the shipments would travel, including Nevada. However, to highlight the impacts that could occur in Nevada, DOE has chosen to discuss them separately. DOE is looking at three transportation scenarios for Nevada. These scenarios include legal-weight truck and rail, which are the same as the national scenarios but highlight the Nevada portion of the transportation, and heavy-haul truck. The heavy-haul truck scenario includes the construction of an intermodal transfer station with associated highway improvements for heavy-haul trucks in the State. DOE has identified five potential rail corridors leading to Yucca Mountain and three potential intermodal transfer station locations with five associated potential highway routes for heavy-haul trucks. Section 2.1.3.3 describes these implementing alternatives.

2.1.1.5 Continuing Investigation of Design Options

As noted, this EIS describes and evaluates the flexible design concept for the repository and current plans for repository construction, operation and monitoring, and closure (see Section 2.1.2). DOE continues to investigate design options for possible incorporation in the final repository design; Appendix E identifies design features that DOE is considering for the final design (for example, specific design and operational considerations regarding natural ventilation and its duration; consideration of indefinite ventilation period; modular construction of repository facilities; whether to handle commercial spent nuclear fuel using a pool with water or a dry transfer system; and site access road construction). The criteria for selecting these design options are related to improving or reducing uncertainties in repository performance (the potential to provide containment and isolation of radionuclides) and operation (for example, worker and operational safety, ease of operation).

DOE has assessed each of the design options still being considered for the expected change it would have on short- and long-term environmental impacts and has compared these impacts to the potential impacts determined for the packaging, operating mode, and transportation scenarios evaluated in the EIS. This assessment, which is described in Appendix E, found that the changes in environmental impacts for the design options would be relatively minor in relation to the potential impacts evaluated in this EIS. Therefore, DOE has concluded that the analytical scenarios and implementing alternatives evaluated in this EIS provide a representative range of potential environmental impacts the Proposed Action could cause. Chapter 9 discusses mitigation from design options that could be beneficial in reducing impacts associated with repository performance or operation.

2.1.2 REPOSITORY FACILITIES AND OPERATIONS

This section describes proposed repository surface and subsurface facilities and operations (Sections 2.1.2.1 and 2.1.2.2), the performance confirmation program (Section 2.1.2.3), and repository closure (Section 2.1.2.4) . The description is based on the Science and Engineering Report (DIRS 153849-DOE 2001, all) and other engineering data files (DIRS 104508-CRWMS M&O 1999, all; DIRS 104523-CRWMS M&O 1999, all; DIRS 102030-CRWMS M&O 1999, all) unless otherwise noted. The following paragraphs contain an overview of the repository facilities and operations and the sequence of planned repository construction, operation and monitoring, and closure. DOE would design the repository based on the extensive information collected during the Yucca Mountain site characterization activities. These activities are summarized in semiannual site characterization reports. [See the semiannual Site Characterization Progress Reports that the Department prepares in accordance with Section 113(b)(3) of the NWPA (for example, DIRS 155982-DOE 2001, all).] The facilities used for site characterization activities at Yucca Mountain would be incorporated in the repository design to the extent practicable. (See Chapter 3, Section 3.1, for additional information on existing facilities at Yucca Mountain developed during site characterization activities.)

DOE would construct surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement. In addition, surface highlight the impacts that could occur in Nevada, DOE has chosen to discuss them separately. DOE is looking at three transportation scenarios for Nevada. These scenarios include legal-weight truck and rail, which are the same as the national scenarios but highlight the Nevada portion of the transportation, and heavy-haul truck. The heavy-haul truck scenario includes the construction of an intermodal transfer station with associated highway improvements for heavy-haul trucks in the State. DOE has identified five potential rail corridors leading to Yucca Mountain and three potential intermodal transfer station locations with five associated potential highway routes for heavy-haul trucks. Section 2.1.3.3 describes these implementing alternatives.

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DOE would construct surface facilities at the repository site to receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement. In addition, surface facilities would support the construction of subsurface facilities. These facilities include the following primary surface operations areas:

- North Portal Operations Area – Receive, prepare, and package spent nuclear fuel and high-level radioactive waste for underground emplacement
- South Portal Development Area – Support the construction of subsurface facilities
- Ventilation Shaft Operations Area – Supply air to and exhaust air from the subsurface facilities

Figure 2-7 is an aerial photograph of the Yucca Mountain site showing the locations of these surface facilities. The spent nuclear fuel and high-level radioactive waste would be handled remotely with workers shielded from *exposure* to radiation using design and operations practices in use at licensed nuclear facilities to the maximum extent practicable. The repository operations areas and supporting areas, utilities, roads, etc., would require the active use of as much as 6 square kilometers (1,500 acres) of land. Of this total area, about 1.5 square kilometers (370 acres) have been disturbed by previous activities.

Figure 2-8 shows the subsurface layout of the repository, which would consist of drifts (tunnels) and vertical ventilation shafts that DOE would excavate in the mountain. Along with the main drifts, gently sloping ramps from the surface to the subsurface facilities would move workers, equipment, and waste packages. Waste packages of spent nuclear fuel and high-level radioactive waste would be placed in the emplacement drifts. The ventilation systems would move air for workers and would cool the repository.

The following paragraphs contain an overview of the sequence of repository construction, operation and monitoring, and closure. Figure 2-9 shows the timing assumed for analysis, site recommendation, site designation, licensing review, construction, operation and monitoring, and closure of the proposed repository at Yucca Mountain. If the Yucca Mountain site was recommended for development as a repository, DOE would continue performance confirmation activities to support a License Application to the Nuclear Regulatory Commission in accordance with the NWPA. Performance confirmation activities after Site Recommendation and before the construction of performance confirmation drifts could be similar to activities performed during site characterization. These activities could require surface excavations and borings, subsurface excavations and borings, and in-place testing of rock characteristics.

The construction of repository facilities for the handling of spent nuclear fuel and high-level radioactive waste would begin after the receipt of construction authorization from the Nuclear Regulatory Commission. DOE assumed that construction would begin in 2005. The repository surface facilities, the main drifts, ventilation system, and initial emplacement drifts would be built in approximately 5 years, from 2005 to 2010 (DIRS 153849-DOE 2001, Section 2.3.5.1.1).

Repository operations would begin after DOE received a license amendment from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For analytical purposes, DOE assumed that the receipt and emplacement of these materials would begin in 2010 and would occur over a 24-year period, unless DOE used aging to implement the lower-temperature repository operating mode. With aging, the emplacement period would be 50 years. DOE also assumed that material receipt would occur at a rate of approximately 3,000 MTHM per year. The emplacement rates discussed here are estimated for analytical purposes only, and would need to be refined should a repository be constructed.

The construction of emplacement drifts would continue for 22 years during emplacement, or would continue until near the end of aging if aging was used to achieve the lower-temperature repository operating mode. The repository design would enable simultaneous construction and emplacement

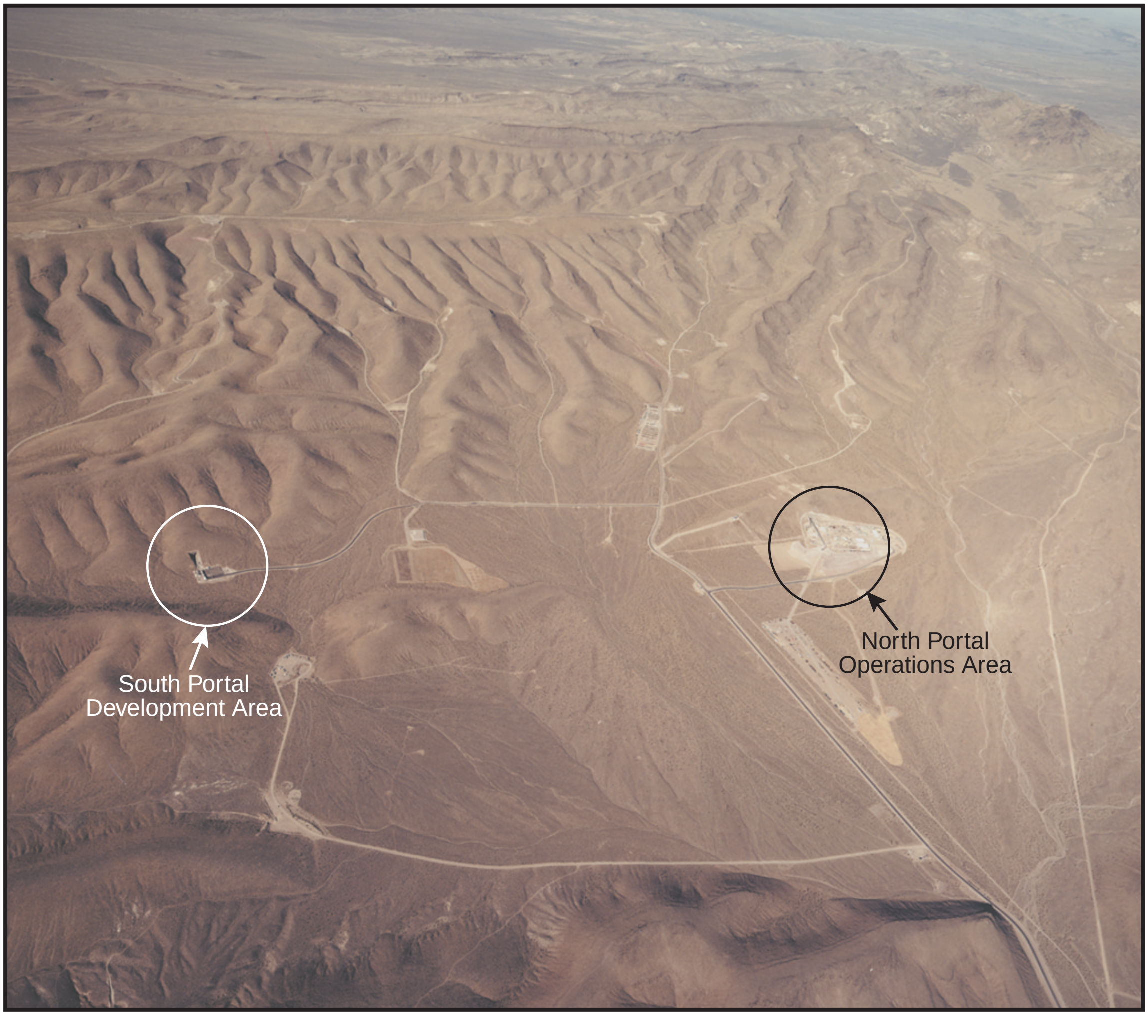

Figure 2-7. Surface facilities at the proposed Yucca Mountain Repository.

operations, and would physically separate activities on the construction or development side of the repository from activities on the emplacement side. This would provide protection of workers and appropriate ventilation of the emplaced waste.

Monitoring and maintenance activities would start with the first emplacement of waste packages and would continue through repository closure. After the completion of emplacement, DOE would maintain those repository facilities, including the ventilation system and utilities (air, water, electric power) that would enable continued monitoring and inspection of the emplaced waste packages, continued investigations in support of estimates of long-term repository performance, and the *retrieval* of waste packages if necessary. Immediately after the completion of emplacement, DOE would decontaminate and close the surface facilities that handled nuclear materials to eliminate any potential radioactive material release and would place surface facilities in a standby condition. That is, they could be reactivated if necessary. DOE would maintain an area in the Waste Handling Building for the possible testing of waste packages as a quality assurance contingency in the performance confirmation program. Future generations would decide whether to continue to maintain the repository in an open, monitored condition or to close it. To ensure flexibility to future decisionmakers, the EIS analyzed the repository with the capability for closure as early as 50 years or as late as 324 years after the start of emplacement based on example scenarios in the Science and Engineering Report (DIRS 153849-DOE 2001, Section 2.1.5). As stated in the Science and Engineering Report, for the higher-temperature repository operating mode, the start of closure could occur as early as 50 years after initial emplacement. The EIS analysis of the higher-temperature operating mode assumes that closure would begin 100 years after the start (76 years after the completion) of emplacement to facilitate comparisons. The lower-temperature repository operating mode would require a longer period of ventilation. This EIS evaluates closure of the repository in the lower-temperature mode after forced ventilation for as many as 324 years after the start of emplacement.

The performance confirmation program would continue some of the activities initiated during site characterization until repository closure, including various types of tests, experiments, and analytical procedures. DOE would conduct performance confirmation activities to further evaluate the accuracy and adequacy of the information used to demonstrate compliance that the repository would meet performance objectives.

Throughout the construction, operation, monitoring and maintenance, and closure periods, the repository would remain under effective institutional control. Under institutional control, the repository would be maintained to ensure that workers and the public were protected adequately in compliance with applicable Federal regulations and the requirements in DOE Order 5400.5 "Radiation Protection of the Public and the Environment."

Repository closure would occur after DOE received a license amendment from the Nuclear Regulatory Commission. Closure would take about 10 years for the higher-temperature repository operating mode (DIRS 150941-CRWMS M&O 2000, p. 6-22), and from 11 to 17 years for the lower-temperature repository operating mode. Closure of the repository facilities would include emplacing the drip shields, closing the subsurface facilities, completely decontaminating and decommissioning the surface facilities, reclaiming the disturbed surface areas, and establishing long-term institutional controls, including land records and warning systems to limit or prevent intentional or unintentional activity in and around the closed repository. DOE would establish a postclosure monitoring program, as required by Section 801(c) of the Energy Policy Act of 1992 (Public Law 102-486, 106 Stat. 2776); the Nuclear Regulatory Commission has regulations (10 CFR Part 63) addressing postclosure monitoring.

2.1.2.1 Repository Surface Facilities and Operations

Surface facilities at the repository site would receive, prepare, stage, and package spent nuclear fuel and high-level radioactive waste for subsurface emplacement. In addition, they would support the construction of the subsurface facilities. DOE would upgrade some surface facilities built for site characterization, but most would be new. Most facilities would be in three areas—the North Portal Operations Area, the South Portal Development Area, and the Ventilation Shaft Operations Areas. Facilities to support waste emplacement would be concentrated near the North Portal, and facilities to support subsurface facility development would be concentrated near the South Portal. The following sections describe these areas in more detail. In addition, Section 2.1.2.1.4 describes support facilities and utilities.

2.1.2.1.1 *North Portal Operations Area*

This area, shown in Figure 2-10, would be the largest of the primary operations areas, covering about 0.6 square kilometer (150 acres) (DIRS 104508-CRWMS M&O 1999, Section 4.2.3.1) at the North Portal. It would include two areas: a *Radiologically Controlled Area* for receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste prior to emplacement, and a Balance of Plant Area for support services (such as administration, training, and maintenance). The Radiologically Controlled Area would be monitored to ensure adequate safeguards and security for radioactive materials. The two example scenarios in the Science and Engineering Report (DIRS 153849-DOE 2001, Section 2.1.5). As stated in the Science and Engineering Report, for the higher-temperature repository operating mode, the start of closure could occur as early as 50 years after initial emplacement. The EIS analysis of the higher-temperature operating mode assumes that closure would begin 100 years after the start (76 years after the completion) of emplacement to facilitate comparisons. The lower-temperature repository operating mode would require a longer period of ventilation. This EIS evaluates closure of the repository in the lower-temperature mode after forced ventilation for as many as 324 years after the start of emplacement.

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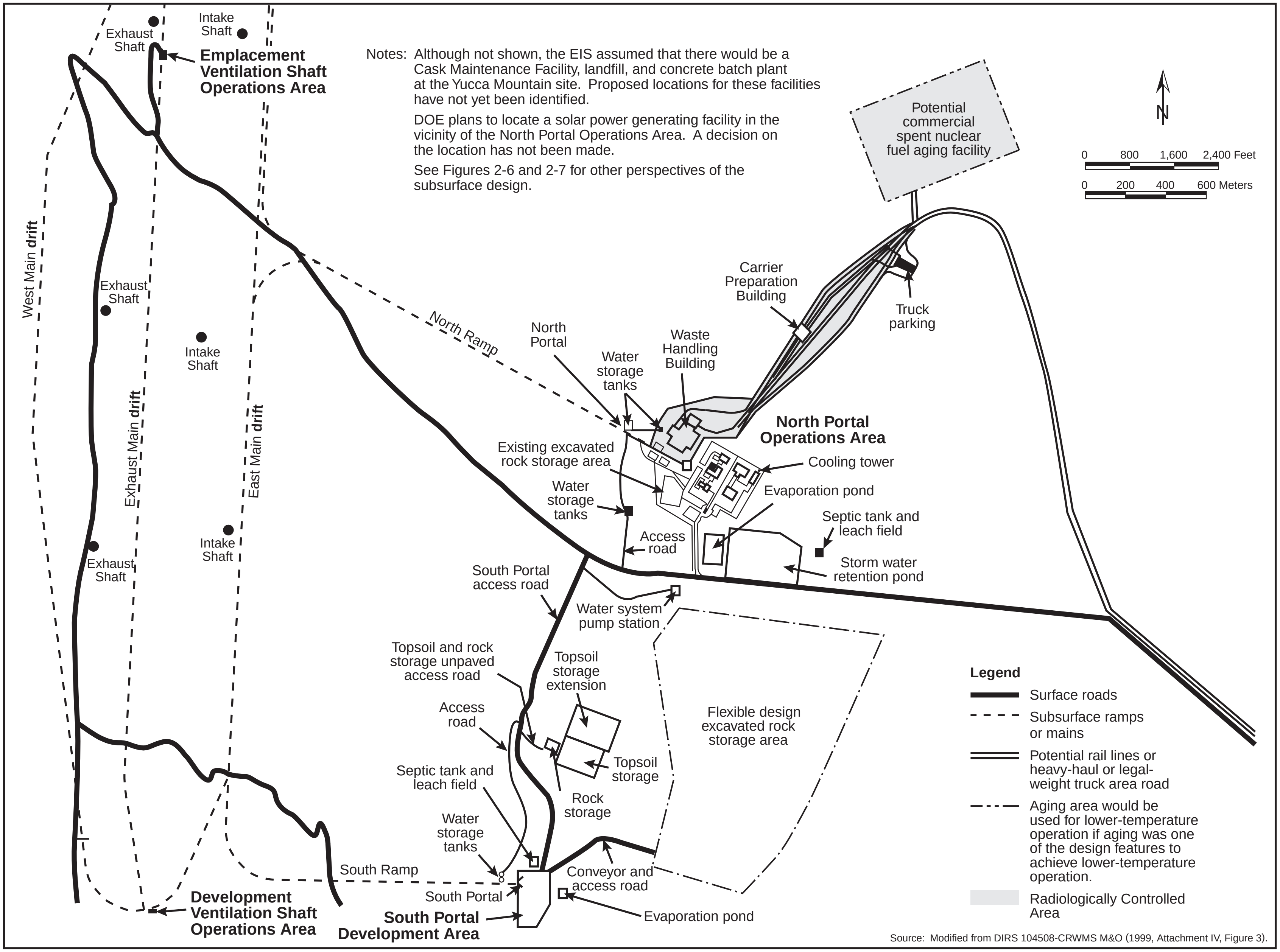

Figure 2-10. Potential repository surface facilities site plan.

principal facilities in the Radiologically Controlled Area for handling spent nuclear fuel and high-level radioactive waste would be the Carrier Preparation Building and the Waste Handling Building. If DOE uses aging to achieve lower-temperature operation, the commercial nuclear fuel aging area would also be included within the Radiologically Controlled Area. Other support facilities in the North Portal Operations Area would include basic facilities for personnel support, warehousing, security, parking and visitors center, and transportation (motor pool). A concrete plant for fabricating and curing precast components and supplying concrete for *in-situ* placement would be near the North Portal Operations Area.

2.1.2.1.1.1 Waste Handling. When a legal-weight or heavy-haul truck or a railcar (depending on the transportation mode) hauling a *cask* containing spent nuclear fuel or high-level radioactive waste arrived at the repository site, it would move through the security check into the Radiologically Controlled Area parking area or to the Carrier Preparation Building. Operations in the Carrier Preparation Building would include performing inspections of the vehicle and cask, removing barriers from the vehicle that protected personnel during shipment, and removing *impact limiters* from the cask. The vehicle would then move to the Waste Handling Building for unloading.

At the Waste Handling Building carrier bay, the carrier/cask handling system would lift the transportation cask to a vertical position and place it on a cask transfer cart. Depending on the cask's contents, the cart would move to one of two transfer systems. Casks that contain disposable canisters (for example, DOE canisters that would not be opened but transferred, as is, directly into a *disposal container*) would go to the canister transfer system. Casks that contain commercial spent nuclear fuel in dual-purpose canisters or individual *fuel assemblies* would go to the assembly transfer system. Figure 2-11 is a flow diagram of Waste Handling Building operations.

The Waste Handling Building would have one canister transfer line that moves the disposable canisters through the building to prepare the waste for emplacement in the repository. The system would move arriving casks through an *air lock* on a transfer cart into a cask preparation area. Once a cask arrived inside the cask preparation area, workers would use remotely operated equipment to vent and sample gases from the cask, remove the lid bolts, and open the cask. An overhead crane would move the cask to a transfer cart, which would take the cask to a shielded transfer area. Inside the transfer area, machines would remove the canister from the cask. The canister could go directly into a disposal container for repository emplacement, or to a holding rack for later placement in a disposal container. Another transfer cart would move loaded disposal containers to the disposal container handling system. A transfer cart would move the empty transportation casks back to the cask *decontamination* area, where they would be surveyed and decontaminated, if required, before return shipment. From the decontamination area, casks would be moved to the carrier/cask handling system, which would place them back on a transporter. The empty cask and cask transporter would return to the Carrier Preparation Building to be readied for offsite shipment.

The Waste Handling Building would also have two assembly transfer lines. Each line would operate independently to handle waste throughput and support maintenance operations. The assembly transfer process would begin by moving the cask on a transfer cart through the air lock into the cask preparation area. Once inside the cask preparation area, workers would use remotely operated equipment to inspect, vent, and cool the cask and remove the cask lid bolts. A large overhead crane would lift the casks and place them in a cask unloading pool, where fuel-handling machines would open the casks and unload the fuel assemblies. If the cask contained dual-purpose canisters, they would be removed and placed in an overpack, where the top of the canister would be cut off. The system would move the empty casks and dual-purpose containers back out through the cask decontamination area. The fuel-handling machines would transfer the fuel assemblies, one at a time, to a holding pool, where they would be placed in assembly baskets. A transfer cart would move the baskets containing the fuel assemblies underwater from the assembly holding pool through a transfer canal to a fuel-blending inventory pool. (See

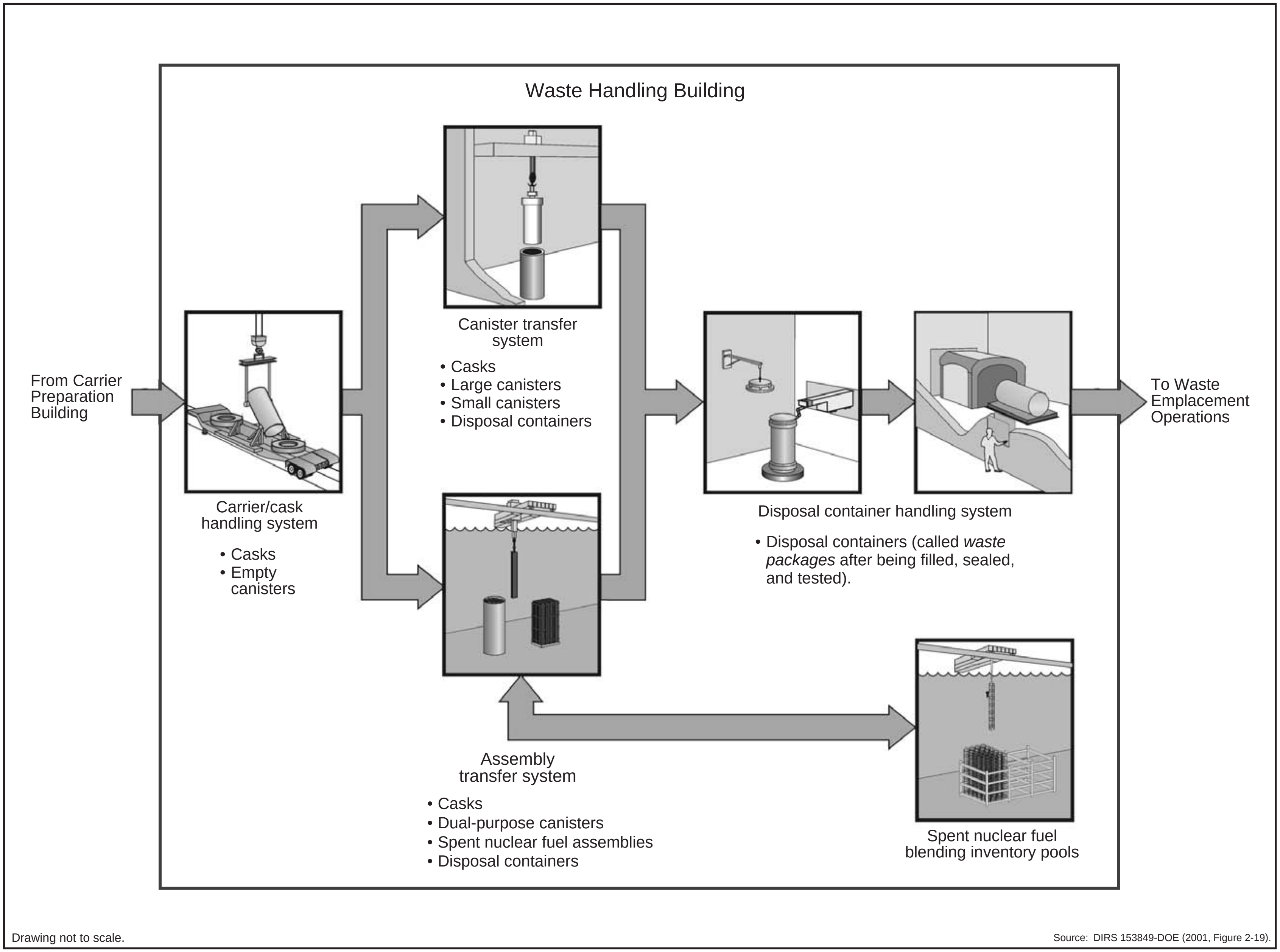

Figure 2-11. Key components of Waste Handling Building operations.

Section 2.1.2.1.1.2 for further information on the processes for blending, use of small waste packages, and aging to meet the flexible design linear thermal load criteria.) When a fuel assembly was selected from the fuel inventory pool for packaging, a transfer cart would move it underwater back through the fuel blending pool to an inclined transfer canal and onto a cart that connects to the assembly drying area.

After fuel assemblies arrived at the assembly drying area, a fuel-handling machine would transfer them into one of two drying vessels. After drying, the system would retrieve the assemblies and transfer them, one at a time, to a disposal container. The empty assembly baskets would be returned to the pool area for reuse. After installation of the sealing device and the inner lid, the system would then evacuate the disposal container internal cavity and fill it with nitrogen gas to exclude oxygen and prevent corrosion from the inside of the waste package. Finally, the transfer cart would transfer the container to the lid welding and inspection area.

The disposal container handling system would receive loaded disposal containers from both the canister transfer system and the assembly transfer system. Each disposal container would again be evacuated and filled with helium, after which the container's lids would be welded and the welds inspected. If the welds meet inspection criteria, the sealed disposal container would be reclassified as a waste package. A crane would transfer the waste package to the transporter loading area, where it would be decontaminated and placed on a pallet, then on a transporter for emplacement in the subsurface repository.

For more details on waste handling, see Section 2.2.4.2 of the Science and Engineering Report (DIRS 153849-DOE 2001).

2.1.2.1.1.2 Approach to Fuel Blending. Spent nuclear fuel and high-level radioactive waste arriving at the repository would be in solid form, but in a variety of types and sizes. Hence, the materials would arrive in a variety of transportation casks, all certified for use by the Nuclear Regulatory Commission. Commercial spent nuclear fuel would arrive as either individual fuel assemblies placed directly into transportation casks, or in dual-purpose canisters in transportation casks that would have to be opened to remove the fuel assemblies. DOE spent nuclear fuel and high-level radioactive waste would arrive in disposable canisters (that is, canisters that would not be opened, but would be transferred directly into a disposal container). Because of the variety of waste forms to be disposed of, about 10 different designs for disposal containers (called waste packages after being loaded, sealed, and certified) would be needed (DIRS 153849-DOE 2001, Section 2.2.1).

The radioactive decay process generates heat. The concentrations of particular isotopes would vary among the different waste forms, and among different fuel assembles in the same type of waste form, so different waste packages would generate different amounts of heat. Because the repository would have established temperature limits, DOE would establish a maximum heat output for all waste packages. For the repository, the maximum heat output would be 11.8 kilowatts per waste package (DIRS 153849-DOE 2001, Section 2.2.1).

The limit on heat output from individual waste packages would impose special considerations for operations and costs. The DOE strategy for controlling heat output would be to load waste packages that mixed low-heat-output spent nuclear fuel with high-heat-output spent nuclear fuel to balance total waste package heat output. This process, called *fuel blending* (DIRS 153849-DOE 2001, Section 2.2.1), would apply only to commercial spent nuclear fuel, which generates much more heat than DOE spent nuclear fuel or high-level radioactive waste (see Appendix A).

To manage heat output, DOE would hold some fuel assemblies in the fuel blending pool in the Waste Handling Building inventory until they generated less heat from radioactive decay or until additional low-heat-output fuel assemblies arrived for blending. The repository would be designed with a fuel blending inventory capacity of approximately 5,000 MTHM, or 12,000 spent nuclear fuel assemblies. By carefully planning and implementing a fuel-blending procedure, DOE could limit and optimize the heat output of the waste packages without increasing their number (DIRS 153849-DOE 2001, Section 2.2.1).

Potential Additional Assembly Transfer Lines in Waste Handling Building. If DOE were to use the smaller waste packages to achieve lower-temperature operation, there would be an increase in the number of assembly transfer lines from two to four. The number of associated hot cells, welding stations, and waste package transporter loading lines would also increase to accommodate the additional canister and waste package handling capacity needed to maintain an emplacement rate of 3,000 MTHM per year. The overall handling process would be the same as that described above.

Potential Commercial Spent Nuclear Fuel Aging Facility. If DOE were to use aging of commercial spent nuclear fuel to achieve the lower-temperature repository operating mode, the aging area would be north and east of the North Portal Operations Area (see Figure 2-10). The spent nuclear fuel aging facility would include access roads, aisles, security fences, and concrete pads to implement the aging process. This area and access to it from the Waste Handling Building would be appropriately restricted for radiation control.

With the use of aging, the handling of commercial spent nuclear fuel would be different than the approach described above because the 5,000-MTHM (12,000 assemblies) blending inventory pools would be unnecessary. Instead, DOE would use a small staging pool for fewer than 80 assemblies for handling processes that required a pool. DOE would replace the assembly transfer system with two dry handling lines, and would add a dry staging hot cell. Commercial spent nuclear fuel would be handled as described above, except it would be loaded into a canister at the surface facility. The canister would be loaded into a dry *storage cask* for movement to and placement on a pad in the aging facility for the duration of the aging period (emplacement with aging is assumed to require 50 years). A motorized or towed transporter, designed to support the aging process, would be used to move the dry storage canister to the aging facility. When the spent nuclear fuel had completed the aging process, it would be transferred from the aging facility to the Waste Handling Building to be placed in a waste package for emplacement as described above.

The Science and Engineering Report (DIRS 153849-DOE 2001), Section 2.1.5, Assessing the Performance of a Lower-Temperature Operating Mode, and Section 2.2, Repository Surface Facilities, provide further detail on the proposed repository higher- and lower-temperature operations. Section 2.2.1 of the Science and Engineering Report provides further discussion on fuel blending strategies and Section 2.2.2.2 provides a more detailed description of the waste handling operations and blending. The essential features for EIS analysis have been presented here.

2.1.2.1.1.3 Generation of Wastes. DOE would decontaminate empty canisters, shipping casks, and related components as required in the Waste Handling Building. After decontamination, the empty canisters and shipping casks would be loaded on truck or rail carriers, sent to the Carrier Preparation Building for processing, and shipped off the site.

Waste generated at the repository from the decontamination of canisters and shipping casks and from other repository housekeeping activities would be collected, processed, packaged, and staged in the Waste Treatment Building before being shipped off the site for disposal at permitted facilities. Waste minimization and pollution prevention measures would reduce the amount of *site-generated waste* requiring such management. For example, decontamination water could be treated and recycled to the extent practicable. Site-generated wastes would include low-level radioactive waste, *hazardous waste*, and *industrial solid waste*. Operations would not be likely, but that could occur, could produce small amounts of mixed wastes (wastes containing both radioactive and hazardous materials). The repository design would include provisions for collecting and storing mixed waste for offsite disposal.

The ventilation systems for the Waste Handling Building and the Waste Treatment Building would provide confinement of radioactive contamination by using pressure differentials to ensure that the air would flow from areas free of contamination to areas potentially contaminated to areas that are normally contaminated. The monitored exhaust air from both buildings would pass through high-efficiency particulate air filters before being released through a single exhaust stack.

2.1.2.1.2 *South Portal Development Area*

The South Portal Development Area would cover about 0.15 square kilometer (37 acres) immediately adjacent to the South Portal of the subsurface facility. The structures and equipment in this area, which would support the development of subsurface facilities, would include steel warehousing, and basic facilities for personnel support, maintenance, warehousing, material staging, security, and transportation. From this area, overland conveyors would transport excavated rock from the repository to the excavated rock storage area (see Figure 2-10).

2.1.2.1.3 *Ventilation Shaft Operations Areas*

The higher-temperature repository operating mode would require three emplacement intake *shafts* and one development intake shaft to support simultaneous development and emplacement activities (see Figure 2-12). Three exhaust shafts would support the full emplacement of 70,000 MTHM. The lower-temperature repository operating mode could require three to seven emplacement intake shafts, one development intake shaft, and five to nine exhaust shafts, depending on the repository layout (DIRS 152003-McKenzie 2000, Option 1, p. 3, and Option 2, p. 3). See Section 2.1.2.2.2 for more discussion of the overall ventilation of the repository and Table 2-2 for a comparative listing.

The Ventilation Shaft Operations Area would have separately developed areas of approximately 0.012 square kilometer (3 acres) each for the emplacement intake, development intake, and exhaust shafts. The total area required for ventilation shafts would range from 0.0085 square kilometer (21 acres) for the higher-temperature operating mode and 0.021 square kilometer (51 acres) for the larger lower-temperature operating mode repository. Each exhaust shaft would contain two 2,000-horsepower fans, with a combined capacity of 800 to 850 cubic meters per second (28,000 to 30,000 cubic feet per second). The ventilation system would be monitored for radioactivity and the air would be filtered as needed.

2.1.2.1.4 *Support Facilities and Utilities*

2.1.2.1.4.1 Storage of Excavated Rock. Repository support facilities and utilities would be on the surface in the general vicinity of the North Portal Operations Area and the South Portal Development Area (see Figure 2-10). The storage area for excavated rock would be the largest support area. The excavated rock storage area for the higher-temperature repository operating mode would be 0.9 square kilometer (220 acres) (DIRS 150941-CRWMS M&O 2000, Figure 6-1). The amount of excavated rock would increase under the lower-temperature repository operating mode as a result of increased waste package spacing. This rock would be stored in the excavated rock storage area, which could be as large as 1.4 square kilometers (347 acres) (DIRS 152003-McKenzie 2000, Option 1, p. 24). Table 2-2 lists the range of the amount of excavated rock for the repository operating modes considered in this Final EIS.

2.1.2.1.4.2 Wastewater and Stormwater Facilities. The repository site would have two evaporation ponds for industrial wastewater, one near the North Portal and one near the South Portal. Sources of industrial wastewater that would go into these ponds include dust suppression water returned to the surface from tunnel boring operations, blowdown from cooling-tower operations at the North Portal, and water from concrete mixing and cleanup. The industrial wastes would be normal operational affluents that would not contain radiological waste and would be processed according to industrial standards and regulations. In both ponds, heavy plastic liners would prevent water migration into the soil.

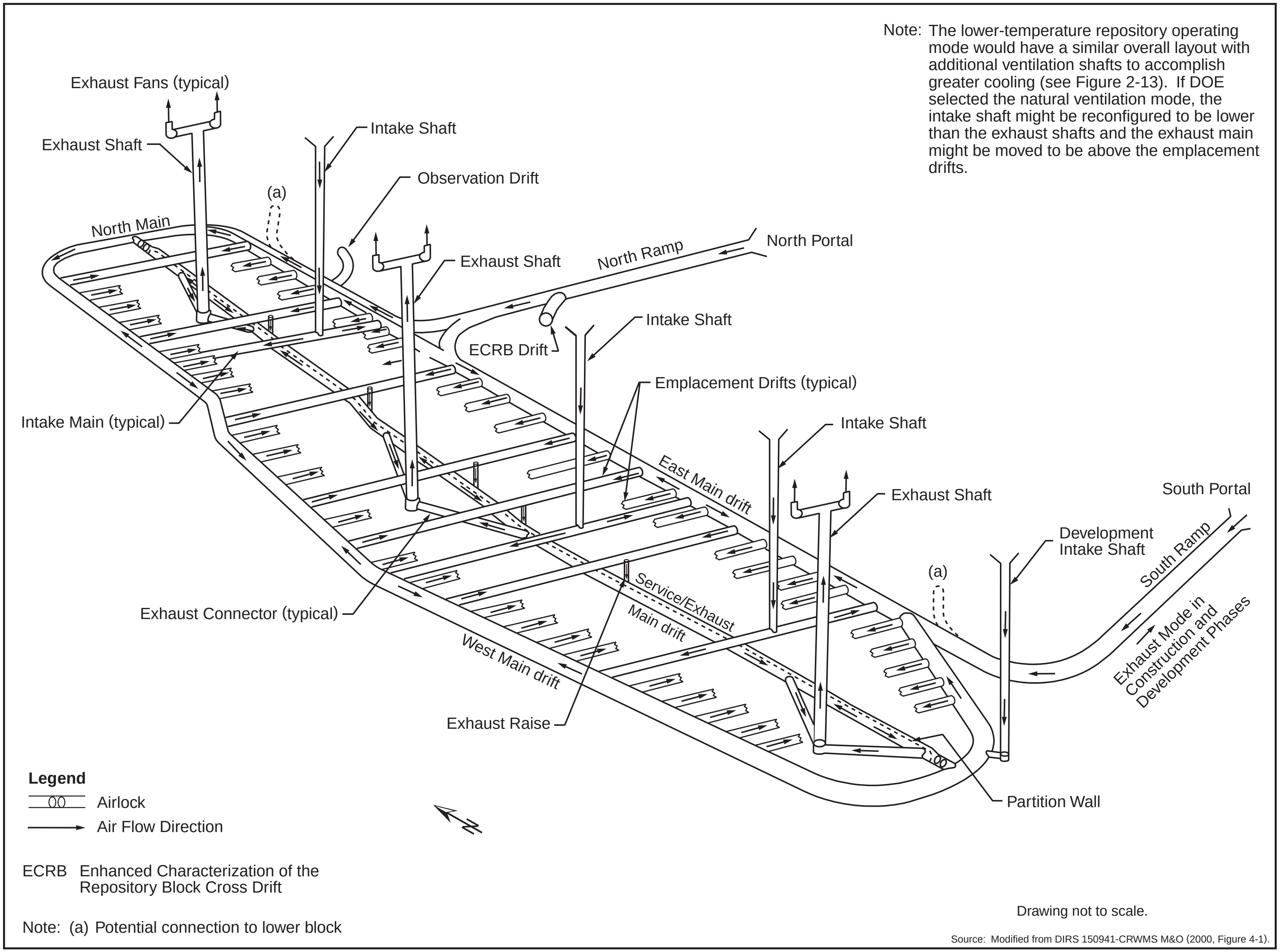

Figure 2-12. Higher-temperature repository operating mode preclosure ventilation air flow in primary block.

The North Portal pond would cover about 0.024 square kilometer (6 acres). The evaporation pond at the South Portal would be about 0.0024 square kilometer (0.6 acre). The North Portal Operations Area would also include an approximately 0.13-square-kilometer (32-acre) stormwater retention pond to control stormwater runoff from the area.

2.1.2.1.4.3 Solid Waste Disposal and Hazardous Waste Management. DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department would develop an appropriately sized landfill [approximately 0.036 square kilometer (9 acres)] at the repository site for nonhazardous and nonradiological construction and *sanitary solid waste* and for similar waste generated during the operation and monitoring and closure phases. The South Portal Development Area would have a septic tank and leach field for the disposal of sanitary sewage. The North Portal Operations Area has an existing septic system that would be adequate for use during repository operations.

2.1.2.1.4.4 Electric Power. The repository would use the Nevada Test Site electric power distribution system, which would require upgrades to handle the demand for the various operational modes considered. At present, electric power at the Yucca Mountain site comes from that system. For the repository, electric power would be distributed throughout the surface and subsurface areas and to remote areas such as the Ventilation Shaft Operations Areas, construction areas, *environmental monitoring* stations, transportation lighting and safety systems, and water wells. To accommodate the expected electric power demand for the repository (estimated to be between 40 and 54 megawatts at peak demand), DOE would upgrade existing electrical transmission and distribution systems. Backup equipment and uninterruptible electric power would ensure personnel safety and operations requiring electric power continuity. Diesel generators and associated switchgear would provide the backup power capability.

In addition, DOE would use electricity from renewable energy sources at the repository (DIRS 153882-Griffith 2001, all). The repository design would include a solar power generating facility, which could produce as much as 3 megawatts of power, and would be a dual-purpose facility, serving as a demonstration of *photovoltaic* power generation and augmenting the overall repository electric power supply (as much as 7 percent). This facility would require about 0.16 square kilometer (40 acres), plus land for an access road and transmission line (DIRS 153882-Griffith 2001, p. 1). The system would be constructed in phases of 500 kilowatts starting in 2005 (DIRS 153882-Griffith 2001, pp. 1 and 6). It would be connected to the repository electric power distribution system. A typical solar power generating facility consists of solar cells (photovoltaic arrays) and support facilities. The solar power generating facility could be in the vicinity of the North Portal Operations Area.

2.1.2.1.4.5 Water Supply. DOE would continue to use existing wells about 5.6 kilometers (3.5 miles) southeast of the North Portal Operations Area to supply water for repository activities for both operating modes. These wells have supplied water for site characterization activities. DOE would seek the necessary authorization to continue withdrawing water from the wells for repository activities. Alternative water sources could include supplying water via truck and pipeline.

Water would be pumped to a booster pump station, then to storage tanks at the North Portal Operations Area and the South Portal Development Area. These elevated tanks would provide gravity-fed water to the distribution systems. At both portal areas, water would go to potable and nonpotable water systems; the nonpotable systems would provide water to fire protection systems, to the supplemental system that would supply deionized water to the fuel storage pools, and to the cooling tower for the heating, ventilation, and air conditioning system.

2.1.2.1.4.6 Fossil Fuel. Fuel supply systems would include fuel oil for a central heating (hot water) plant, which would consist of a main tank and a day tank. In addition, there would be fuel supply systems for fire water system tank heaters, for diesel-powered standby generators and air compressors, and for backup fire pumps. There would also be diesel fuel and gasoline to fuel vehicles during the construction, operation and monitoring, and closure of the repository. In addition, fossil-fuel powered vehicles would maintain the excavated rock storage area.

2.1.2.2 Repository Subsurface Facilities and Operations

DOE would construct the subsurface facilities of the repository and emplace the waste packages above the water table in a mass of volcanic rock (referred to as the *repository block*) known as the Topopah Spring Formation, which consists of *welded tuff* (see Chapter 3, Section 3.1.3.1). The specific area in this formation where DOE would build the repository emplacement drifts would satisfy several criteria: (1) to be in select portions of the Topopah Spring Formation that have desirable properties, (2) to avoid major faults for reasons related to both hydrology and *seismic* hazards (see Section 3.1.3.2), (3) to be at least 200 meters (660 feet) below the surface (DIRS 154554-BSC 2001, Section 4.2.1.2.9, p. 29), and (4) to be at least 160 meters (530 feet) above the present-day water table (DIRS 154554-BSC 2001, Section 4.2.1.2.4 p. 28).

The flexible design would use part or all of the layout shown in Figure 2-13. The smallest area that DOE would use is the shaded area that corresponds to the higher-temperature repository operating mode. DOE would use the full area shown for some of the possible lower-temperature repository operating modes (DIRS 153849-DOE 2001, Section 2.1.5.1).

The higher-temperature operating mode would utilize the upper (primary) block of the repository, using 4.7 square kilometers (1,150 acres) (DIRS 153849-DOE 2001, Section 2.3.1.1) (see Figure 2-13) and would require seven emplacement and development ventilation shafts. The lower-temperature repository operating mode could require as many as 17 ventilation shafts (see Table 2-2).

2.1.2.2.1 *Subsurface Facility Design and Construction*

The subsurface design would incorporate most of the drifts developed during the site characterization activities. Other areas would be excavated during the repository construction phase. Excavated openings would include gently sloping access ramps to enable rail-based movement of construction and waste package handling vehicles between the surface and subsurface, subsurface main drifts to enable the movement of construction and waste package handling vehicles, emplacement drifts for the placement of waste packages, exhaust mains to transfer air in the subsurface area, and ventilation shafts to transfer air between the surface and the subsurface. There would also be performance confirmation (observation) drifts for the placement of instrumentation to monitor emplaced waste packages (see Figure 2-13).

Access ramps connecting the surface and subsurface would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by electric-powered tunnel boring machines (see Figure 2-14). Rail lines and an overhead trolley system would enable the movement of electric-powered construction and waste package handling vehicles. DOE developed the North and South Ramps, which would become part of the proposed repository, during site characterization. The North Ramp begins at the North Portal Operations Area on the surface (see Section 2.1.2.1.1) and extends through the subsurface to the edge of the repository area. It would support waste package emplacement operations. The South Ramp originates at the South Portal Development Area on the surface (see Section 2.1.2.1.2) and extends through the subsurface to the edge of the repository area. It would support subsurface construction and development activities.

The main drifts for the higher-temperature repository operating mode would include the East Main, the West Main, and the North Main. These drifts would be extended for the lower-temperature operating modes and additional main drifts would be excavated to provide access to other emplacement areas.

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The main drifts for the higher-temperature repository operating mode would include the East Main, the West Main, and the North Main. These drifts would be extended for the lower-temperature operating modes and additional main drifts would be excavated to provide access to other emplacement areas.

Main drifts would be concrete-lined, 7.6-meter (25-foot)-diameter tunnels excavated by tunnel boring machines. Rail lines and an overhead trolley system in the main drifts would enable the movement of electric-powered construction and waste package handling vehicles. The East Main drift was excavated as part of site characterization activities but was not lined with concrete. During the operation and monitoring phase, the main drifts would support both subsurface development and waste package emplacement, which would occur simultaneously. Ventilation barriers creating airlocks would separate the emplacement and development sides of the repository, and the ventilation system would maintain the emplacement side at a lower pressure than the development side. This would ensure that any air transfer would be from the development side to the emplacement side.

The flexible design is based on an emplacement drift spacing of approximately 81 meters (266 feet) (DIRS 153849-DOE 2001, Section 2.3.1.1). Emplacement drifts would be 5.5-meter (18-foot)-diameter tunnels connecting the main drifts; they could have steel ribbing. These drifts would be excavated by an electric-powered tunnel boring machine. Remotely operated steel isolation doors at the emplacement drift entrances would prevent unauthorized human access and reduce radiation exposure to personnel.

As noted above, tunnel boring machines would excavate the emplacement drifts and most main drifts. DOE would use other mechanical excavators in areas where tunnel boring machines were impractical (for example, excavating turnouts and small alcoves) or industry-standard drill and blast techniques in limited applications where mechanical excavators were impractical. Ventilation shafts [8.0 meters (26 feet) in diameter] would be excavated from the surface to the repository using mechanical or drill-and-blast techniques. (DIRS 153849-DOE 2001, p. 2-95). Specialized equipment would move excavated rock in the subsurface to the conveyor system that would move the rock to the excavated rock storage area on the surface. During drift excavation, water supplied to the subsurface in pipelines would be used for dust control at the excavation location and along the conveyor carrying excavated rock. Some of the water would be removed from the subsurface with the excavated rock, some would evaporate and be removed in the ventilation air, and the remainder would be collected in sumps near the point of use and pumped to the evaporation pond at the South Portal. DOE could recycle the water discharged to the evaporation pond for surface dust suppression activities. Controls would be established, as necessary, to ensure that water application for subsurface (and surface) dust control would not affect repository performance.

2.1.2.2.2 *Ventilation*

The repository design uses ventilation shafts to provide airflow to the subsurface during construction, emplacement, and performance monitoring. It also provides positive pressure ventilation flow for the construction and development of the repository and negative pressure ventilation flow in the emplacement drifts. Further, the design includes monitoring for radioactive contamination and preventive measures to achieve mitigation against the spread of such contamination. The development side would be isolated from the emplacement side. Table 2-2 lists the number of ventilation shafts and flow rates.

The flexible design uses an emplacement drift forced-air ventilation rate of 15 cubic meters (530 cubic feet) per second in each emplacement drift to control temperatures in the rock between the emplacement drifts, at the drift wall, and at the waste package surface to meet thermal goals. Figure 2-12 shows the general airflow pattern for ventilation of the emplacement drifts under the higher-temperature repository operating mode, using a representative section of a fully developed repository. In the basic ventilation design, fresh air would enter through the surface ends of intake shafts and ramps and would flow to the East and West Mains. From the mains, air would enter the emplacement, performance confirmation, or reserve drifts and flow to exhaust raises near the center of each drift. The exhaust raises would direct the airflow down to the exhaust main, where it would continue to an exhaust shaft and then to the surface.

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Fans at the surface ends of the exhaust shafts would provide the moving force for the subsurface repository airflow. The fans would have enough power to exhaust the maximum amount of air required during the emplacement, monitoring, and closure periods. The volume of air moved by the fans would be adjustable to meet cooling requirements as they varied over time. The fans would draw air through the exhaust mains at a rate that ensured that air would always flow into the emplacement drifts from the main drifts, never allowing air to recirculate back to the main drifts.

Ventilation under the higher-temperature repository operating mode would remove at least 70 percent of the heat generated by the waste inventory during the preclosure period (DIRS 153849-DOE 2001, Section 2.1.2.2). The peak ventilation air temperature of 58°C (about 136°F) for a 1.4-kilowatt-per-meter linear thermal load would occur about 10 years into the preclosure period and would decrease thereafter (DIRS 150941-CRWMS M&O 2000, pp. 4-24 to 4-25). This temperature is lower than the exhaust air temperature of many industrial processes, such as powerplants and manufacturing facilities. The peak ventilation air temperature under the lower-temperature repository operating mode would be lower than that described above.

Ventilation requirements for emplacement drifts would vary according to the activities conducted in those drifts. Prior to emplacement, ventilation would provide fresh air and control dust levels to ensure an acceptable environment for construction personnel. During emplacement, ventilation would maintain drift temperatures within an acceptable range for equipment operation.

While DOE was conducting concurrent development and emplacement operations, it would maintain two separate ventilation systems, one for each operational area (development and emplacement). This separation would be accomplished by placing airlocks in the main drifts to ensure physical separation of the air space between the two areas. On the development side, the ventilation system would work under positive pressure, with air forced in through the development intake shaft or the South Ramp through a duct and exhausted through the South Ramp. On the emplacement side, the required ventilation facilities for the commissioned emplacement drifts would be available and operational in their final configuration; the ventilation system would work under negative pressure by drawing air out through the exhaust main (through the exhaust or “hot” side of the exhaust main), and from there through the exhaust shafts.

2.1.2.2.3 *Waste Package Emplacement Operations*

DOE would transport both the waste package and metal emplacement pallet as an integral unit from the Waste Handling Building to the prepared *ground support* in the emplacement drift. The transport of each waste package to the subsurface would start after the loading of a waste package and its emplacement pallet on a bedplate (railcar) transporter in the Waste Handling Building and then into the shielded section of the transporter. At its closed end the transporter would be coupled to a manned primary electric-powered locomotive (trolley). A manned secondary electric-powered locomotive would then be coupled to the transporter at the door end outside the Waste Handling Building (DIRS 153849-DOE 2001, Section 2.3.4.4.1). All waste packages would be transported by trolley underground through the North Ramp and into the emplacement area main drift. On arrival at the emplacement drift, the secondary locomotive would be uncoupled from the transporter, which would then be pushed into the emplacement drift turnout by the primary locomotive and stopped short of the isolation doors and loading dock. The operators would leave, and the locomotive operation would proceed by remote control. The isolation doors would be opened remotely, as would the transporter doors. Under remote control, the primary locomotive would push the waste package transporter into the off-loading dock. The waste package and pallet, seated on the bedplate, would be rolled out of the transporter, under remote control, to stop on the transfer section of the railcar. The remote-controlled gantry would straddle the waste package and pallet, lift the waste package and pallet from the bedplate, and carry them to the designated location in the emplacement drift. The bedplate would be rolled back into the waste package transporter, the transporter doors would be closed, and the transporter would be moved back to the access main drift using the

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DOE has developed plans for waste package retrieval for normal and off-normal conditions. Waste package retrieval under normal conditions would use the same subsurface equipment and facilities as emplacement, but in reverse order. This would provide a built-in capability for retrieval that could be readily implemented. Individual waste package removal for inspection, testing, and maintenance reasons is not considered retrieval; however, waste package removal for these purposes, if needed, would involve the same equipment and operational steps. Alternative waste package retrieval equipment and processes have been identified for off-normal conditions when normal retrieval procedures could be difficult or impossible to execute. Additionally, support equipment (equipment to remove obstacles, prepare surfaces, or install temporary ground supports) that could be used in retrieval operations under off-normal conditions has been identified. The equipment and processes would support various scenarios such as repair of the railing system, repositioning the emplacement pallet and waste package, or cleaning or removal of debris. All retrieval scenarios include radiation and temperature controls and other administrative controls, as needed, to conduct a safe retrieval operation (see DIRS 153849-DOE 2001, Section 2.3.4.6).

2.1.2.2.4 *Engineered Barrier Design*

Engineered barriers would include those components in the emplacement drifts that would contribute to waste containment and isolation. The design includes the following components as engineered barriers: (1) waste package, (2) emplacement drift *invert*, (3) *drip shield*, and (4) to a lesser extent, ground support (DIRS 153849-DOE 2001, Section 2.4). The following sections describe the details of these components.

2.1.2.2.4.1 Waste Package and Drip Shields. The function of the waste package would change over time. During the operation and monitoring phase, the waste packages would function as the vessels for safely handling, emplacing and, if necessary, retrieving their contents. After closure, the waste packages would be the primary engineered barrier to inhibit the release of radioactive material to the environment. The waste package design consists of two closed concentric cylinders in which DOE would place the waste forms.

The waste package would have a corrosion-resistant *Alloy-22* outer shell and a stainless-steel (Type 316NG) inner shell to provide structural support (DIRS 153849-DOE 2001, Section 3). Alloy-22 consists mostly of nickel, chromium (up to 22.5 percent), and molybdenum (up to 14.5 percent). Type 316NG stainless steel consists mostly of iron, chromium (up to 18 percent), nickel (up to 14 percent), and molybdenum (up to 3 percent) (DIRS 153849-DOE 2001, Section 3.4.1.1). In addition, the waste package would have a top lid design that consisted of three lids. The innermost lid would be stainless steel welded to the stainless-steel shell. The middle and outer lids would be Alloy-22, welded to the Alloy-22 outer shell (DIRS 153849-DOE 2001, Section 3) (see Figure 2-15). The highly corrosion-resistant Alloy-22 outer shell of the waste package would protect the underlying structural material from corrosive degradation, while the strong internal structural material would support the thinner corrosion-resistant material.

A drip shield with a nominal thickness of 1.5 centimeters (0.6 inch) of highly corrosion-resistant titanium would be placed over the waste package just before repository closure. The titanium drip shield and the Alloy-22 outer cylinder would provide two diverse engineered corrosion barriers to protect the waste from contact with water. The use of two distinctly different corrosion-resistant materials would reduce the *probability* that a single mechanism could cause the failure of both materials. Figure 2-16 shows a side view of a drip shield and an end view of the waste package and drip shield.

primary locomotive under remote control. The isolation doors in the turnout would be closed, allowing the locomotive operators to recouple the secondary locomotive to the railcar. The empty transporter would be returned to the Waste Handling Building to pick up the next waste package (DIRS 153849-DOE 2001, Section 2.3.4.4.1).

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2.1.2.2.4 *Engineered Barrier Design*

Engineered barriers would include those components in the emplacement drifts that would contribute to waste containment and isolation. The design includes the following components as engineered barriers: (1) waste package, (2) emplacement drift *invert*, (3) *drip shield*, and (4) to a lesser extent, ground support (DIRS 153849-DOE 2001, Section 2.4). The following sections describe the details of these components.

2.1.2.2.4.1 Waste Package and Drip Shields. The function of the waste package would change over time. During the operation and monitoring phase, the waste packages would function as the vessels for safely handling, emplacing and, if necessary, retrieving their contents. After closure, the waste packages would be the primary engineered barrier to inhibit the release of radioactive material to the environment. The waste package design consists of two closed concentric cylinders in which DOE would place the waste forms.

The waste package would have a corrosion-resistant *Alloy-22* outer shell and a stainless-steel (Type 316NG) inner shell to provide structural support (DIRS 153849-DOE 2001, Section 3). Alloy-22 consists mostly of nickel, chromium (up to 22.5 percent), and molybdenum (up to 14.5 percent). Type 316NG stainless steel consists mostly of iron, chromium (up to 18 percent), nickel (up to 14 percent), and molybdenum (up to 3 percent) (DIRS 153849-DOE 2001, Section 3.4.1.1). In addition, the waste package would have a top lid design that consisted of three lids. The innermost lid would be stainless steel welded to the stainless-steel shell. The middle and outer lids would be Alloy-22, welded to the Alloy-22 outer shell (DIRS 153849-DOE 2001, Section 3) (see Figure 2-15). The highly corrosion-resistant Alloy-22 outer shell of the waste package would protect the underlying structural material from corrosive degradation, while the strong internal structural material would support the thinner corrosion-resistant material.

A drip shield with a nominal thickness of 1.5 centimeters (0.6 inch) of highly corrosion-resistant titanium would be placed over the waste package just before repository closure. The titanium drip shield and the Alloy-22 outer cylinder would provide two diverse engineered corrosion barriers to protect the waste from contact with water. The use of two distinctly different corrosion-resistant materials would reduce the *probability* that a single mechanism could cause the failure of both materials. Figure 2-16 shows a side view of a drip shield and an end view of the waste package and drip shield.

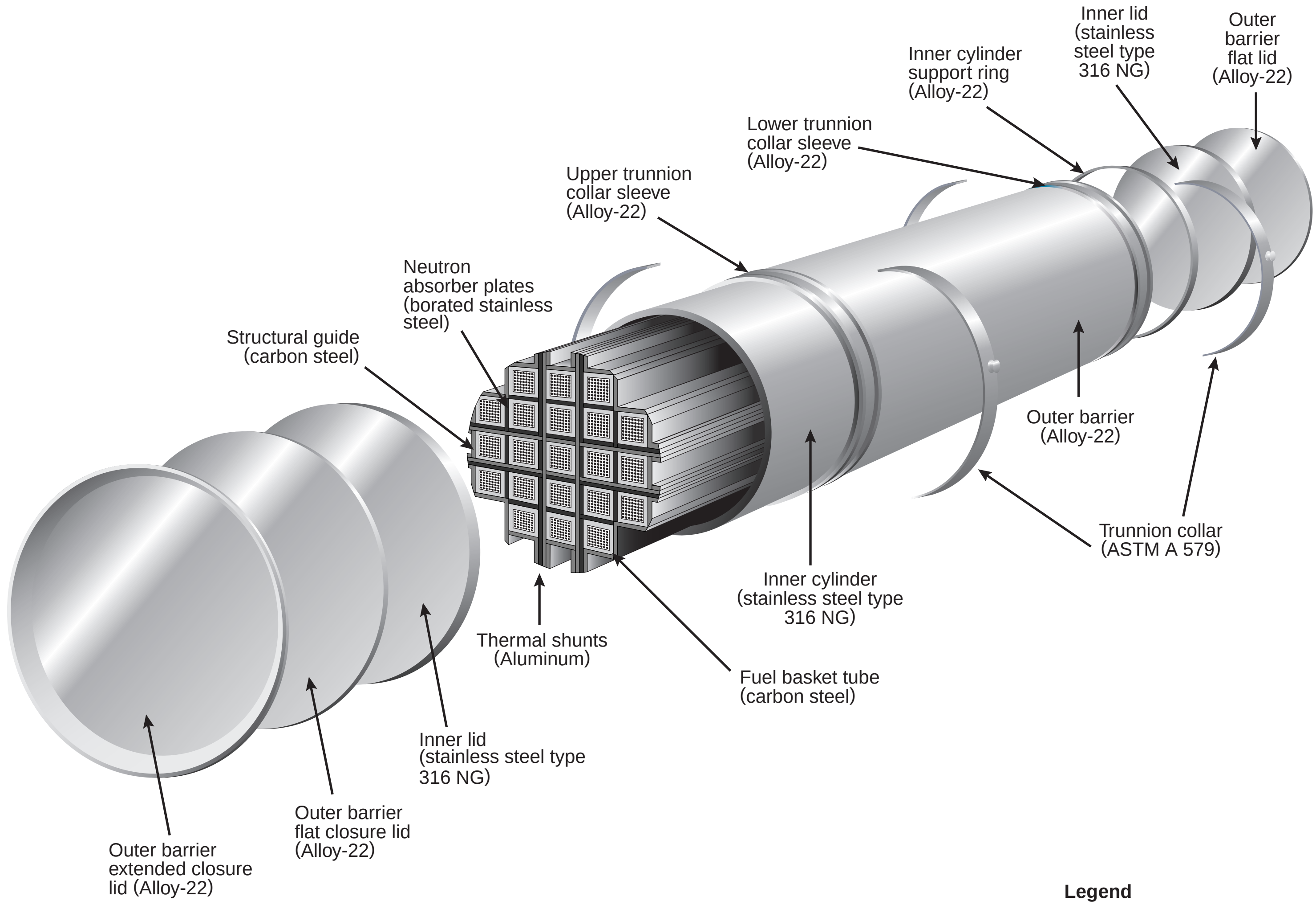


Figure 2-15. Waste package for commercial spent nuclear fuel (pressurized-water reactor waste package).

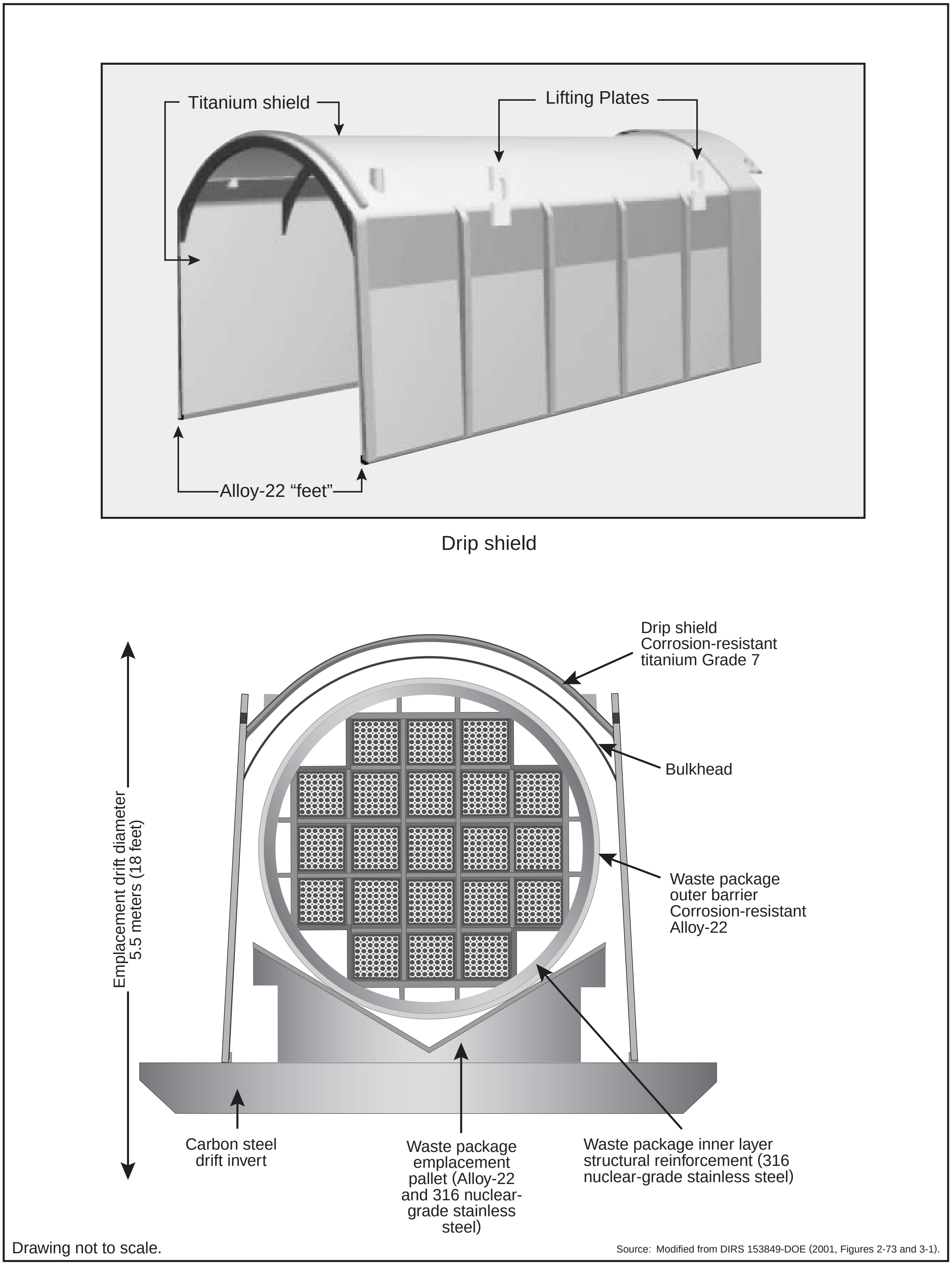


Figure 2-16. Drip shield and waste package containing commercial spent nuclear fuel with drip shields in place.

Commercial spent nuclear fuel, DOE spent nuclear fuel, and immobilized plutonium contain *fissile material,* which is material capable, in principle, of sustaining a fission *chain reaction*. For a self-sustaining chain reaction to take place, a critical mass of fissile material—uranium-233 or -235 or one of several plutonium isotopes—must be arranged in a critical configuration. Waste packages would be loaded with fissile material and *neutron absorbers*, if needed, so *criticality* could not occur even in the unlikely event that the waste package somehow became full of water.

After the repository ventilation was stopped and heat produced by the waste packages had decreased (both of which would happen after closure), moisture could enter the emplacement drifts in liquid or vapor form. The function of the drip shields would be to divert water that dripped from the drift walls and water vapor that condensed on the surface of the drip shields away from waste packages, prolonging their longevity and structural integrity. Water dripping on the waste packages would increase the likelihood of corrosion. For the EIS analyses, the drip shields were considered to be a single continuous barrier for the entire length of the emplacement drift if the separation between the waste packages was less than 1.6 meters (5.3 feet). If the separation was greater than 1.6 meters, the EIS analyses used stand-alone drip shields. They would be strong enough to protect the waste packages from damage by rockfalls resulting from degradation of the drift walls, withstanding damage from rocks weighing several tons (DIRS 153849-DOE 2001, Section 2.4.4). To maintain waste package retrievability, the drip shields, via remote control, would be placed over the waste packages just before repository closure.

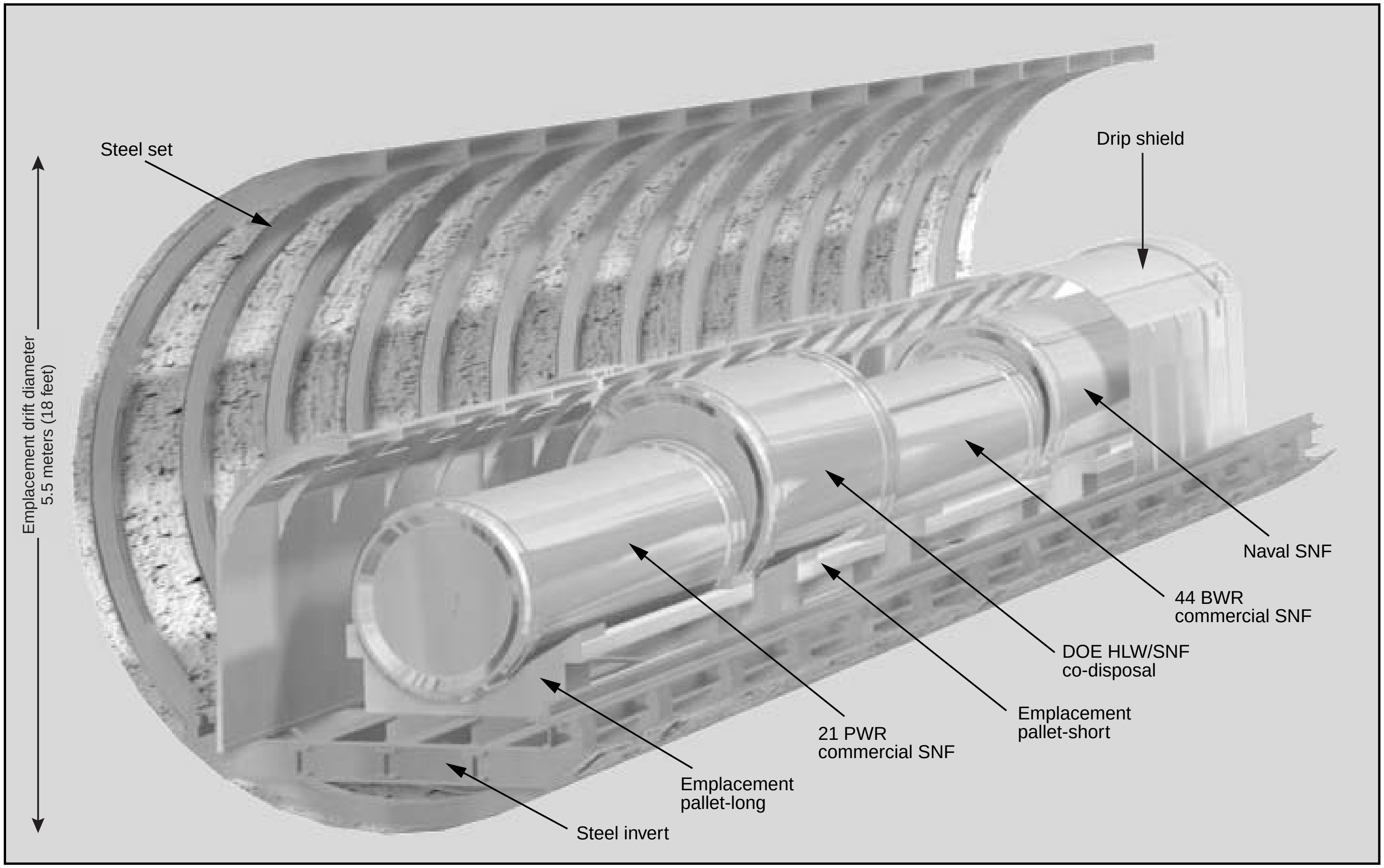
2.1.2.2.4.2 Ground Support Structures. In underground openings, ground support structures provide tunnel stability and help prevent rockfall. For the proposed repository, the ground support system would address in-place loads, construction loads, potential loads from repository operations, and loads from potential seismic occurrences (DIRS 153849-DOE 2001, Section 2.3.4.1.2). The system would consist of steel sets with welded-wire fabric and fully grouted rockbolts.

The main drifts, turnouts, exhaust main, and ventilation shafts (nonemplacement areas) would have separate initial and final ground support systems. Initial ground support methods would vary depending on ground conditions, and would include a combination of steel sets, welded-wire fabric, rockbolts, and shotcrete (concrete sprayed onto the surface at high pressure). The final ground support system for the nonemplacement drift areas would be cast-in-place concrete liners.

The observation drifts, which would support the performance confirmation program, would have a ground support system similar to that for the emplacement drifts if they were excavated with a tunnel boring machine. Otherwise, they would have a combination of support systems, including steel sets, welded-wire fabric, rockbolts, and shotcrete, depending on ground conditions (DIRS 153849-DOE 2001, Section 2.3.4.1.2.2).

2.1.2.2.4.3 Emplacement Pallets. The repository design uses emplacement pallets to support the waste packages. A waste package would be placed horizontally on its support (an emplacement pallet) in the Waste Handling Building and transported to the drifts as a unit. Figure 2-17 shows a conceptual design of spent nuclear fuel and high-level radioactive waste package types in an emplacement drift on emplacement pallets, drip shields, and steel sets for ground support. The emplacement pallet would support the waste package in the drift. While loaded with a waste package, the pallet would be lifted by lifting points at the support, directly under the upper stainless-steel tubes, as shown in Figure 2-18. The pallet design would meet the design requirements for structural strength during lifting under the weight of the heaviest waste package (DIRS 153849-DOE 2001, Section 2.3.4.4.2).

Figure 2-19 shows an emplacement pallet, and Figure 2-18 shows a waste package on an emplacement pallet. There would be two sizes of pallet: one that would hold most waste packages and a second, shorter version for the DOE codisposal waste package (DIRS 153849-DOE 2001, Section 2.3.4.4.2). The emplacement pallets would be made of Alloy-22 plates welded together to form the waste package



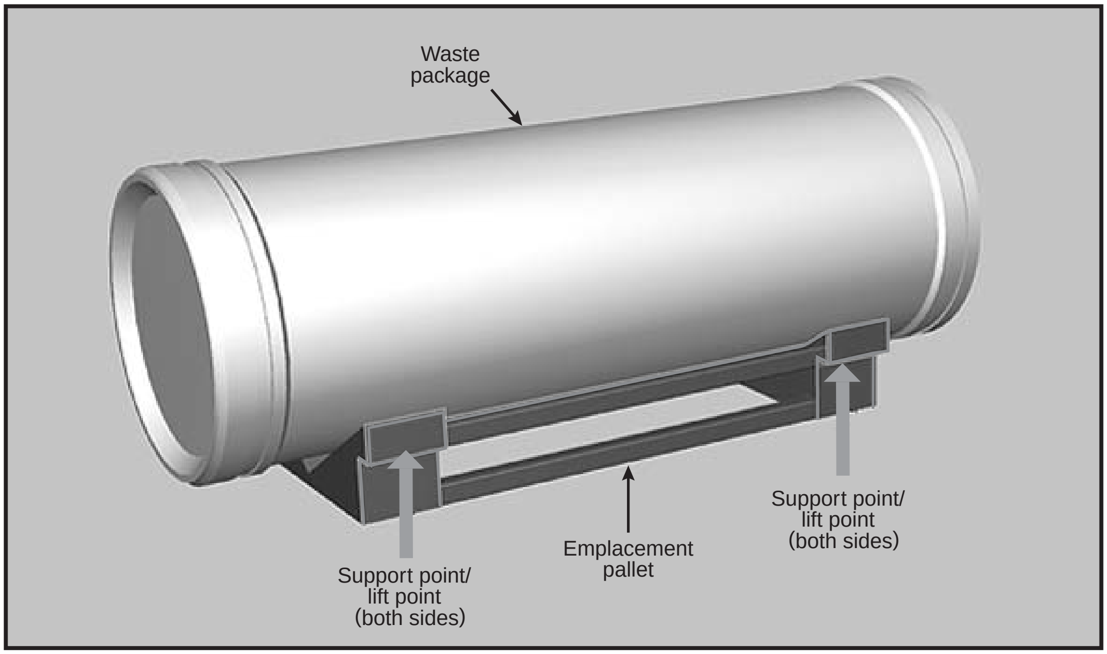
Drawing not to scale.

Legend

- BWR Boiling-water reactor
- DOE U.S. Department of Energy
- HLW High-level radioactive waste
- PWR Pressurized-water reactor
- SNF Spent nuclear fuel

Source: Modified from DIRS 153849-DOE (2001, Figure 2-77).

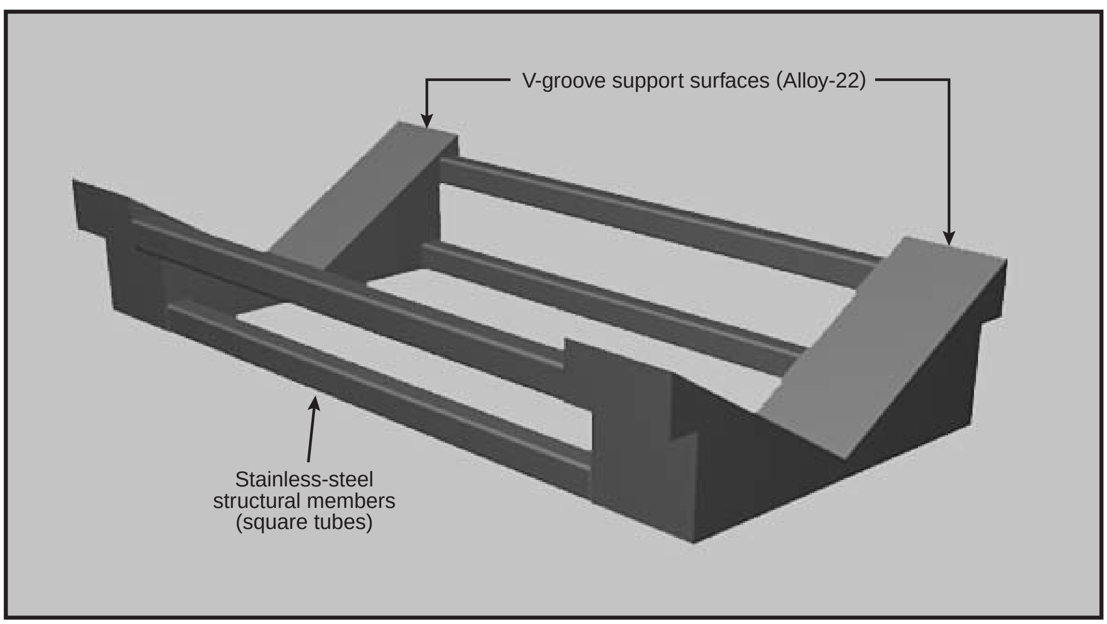
Figure 2-17. Typical section of emplacement drift with waste packages and drip shields in place.



Drawing not to scale.

Source: DIRS 153849-DOE (2001, Figure 2-52).

Figure 2-18. Waste package on an emplacement pallet.



Drawing not to scale.

Source: DIRS 153849-DOE (2001, Figure 2-51).

Figure 2-19. Emplacement pallet.

supports. Two supports would be connected by square stainless-steel tubing to form the completed emplacement pallet. The supports would have a V-groove top surface to accept all waste package diameters. Emplacement pallet surfaces that contacted the waste package would be Alloy-22, the same material used for the outer package shell.

The ends of the waste package would extend past the ends of the emplacement pallet, which would allow placement of the waste packages end-to-end, within 10 centimeters (4 inches) of each other, without interference from the pallets (DIRS 153849-DOE 2001, Section 2.3.4.4.2).

2.1.2.3 Performance Confirmation Program

Performance confirmation refers to the program of tests, experiments, and analyses that DOE would conduct to evaluate the adequacy of the information used to demonstrate compliance that the repository would meet performance objectives. The performance confirmation program, which would continue through the licensing and construction phases and until the closure phase, would include elements of site testing, repository testing, repository subsurface support facilities construction, and waste package testing. Some of these activities would be a continuation of activities that began during site characterization.

To support performance confirmation activities, DOE would provide some specialized surface and subsurface facilities. DOE would build observation drifts below and above the *repository horizon* (DIRS 153849-DOE 2001, Section 2.5.2.2). The data-collection focus of the performance confirmation program would be to collect additional information to confirm the data used in the License Application. If the Nuclear Regulatory Commission granted a license, the activities would focus on monitoring and data collection for performance parameters important to terms and conditions of the license.

Performance confirmation drifts would be built about 15 meters (50 feet) above and below the emplacement drifts. DOE would drill boreholes from the performance confirmation drifts that would approach the rock mass near the emplacement drifts; instruments in these boreholes would gather data on the thermal, mechanical, hydrological, and chemical characteristics of the rock after waste emplacement. DOE would acquire performance confirmation data by sampling and mapping, from instruments in performance confirmation drifts or along the perimeter mains, ventilation exhaust monitoring, remote inspection systems in emplacement drifts, and monitoring of water quality in wells.

DOE would use the performance confirmation program data to evaluate system performance and to confirm predicted system response. If the data determined that actual conditions differed from those predicted, the Nuclear Regulatory Commission would be notified and remedial actions would be undertaken to address any such condition (DIRS 153849-DOE 2001, Sections 2.5 and 4.6).

2.1.2.4 Repository Closure

Before closure, an application to amend the Nuclear Regulatory Commission license would have to provide an update of the assessment of repository performance for the period after closure, as well as a description of the program for postclosure monitoring to regulate or prevent activities that could impair the long-term isolation of waste. The postclosure monitoring program, as required by Section 801(c) of the Energy Policy Act of 1992 and as required by the Nuclear Regulatory Commission (10 CFR Part 63), would include the monitoring activities that would be conducted around the repository after the facility had been closed and sealed. Regulations at 10 CFR 63.51(a)(1) and (2) would require the submittal of a license amendment for closure of the repository (see Section 2.3.4.8). The details of this program would be delineated during processing of the license amendment for closure. Deferring the delineation of this program to the closure period would allow identification of appropriate technology, including technology that might not be currently available (DIRS 153849-DOE 2001, Sections 2.3.4.8 and 4.6.1).

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For the higher-temperature repository operating mode, this EIS assumes closure would begin 100 years after the start of emplacement (76 years after the completion of emplacement). In contrast, repository closure for the lower-temperature repository operating mode could begin 125 to 300 years after the completion of emplacement. Closure would take 10 years for the higher-temperature mode (DIRS 150941-CRWMS M&O 2000, p. 6-22) and between 11 and 17 years for the lower-temperature mode, depending on the waste package spacing.

Closure of the subsurface repository facilities would include the emplacement of the drip shields; removal and salvage of equipment and materials; filling of the main drifts, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and boreholes. Filling would require surface operations to obtain fill material from the excavated rock storage area or another source, and processing (screening, crushing, and possibly washing) the material to obtain the required characteristics. Fill material would be transported on the surface in trucks and underground in open gondola railcars. A fill placement system would place the material in the underground main drifts and ramps. DOE would place the seals for shafts, ramps, and boreholes strategically to reduce *radionuclide* migration over extended periods, so these openings could not become pathways that could compromise the repository's postclosure performance (DIRS 153849-DOE 2001, Section 2.3.4.8).

Decommissioning surface facilities would include decontamination activities, if required, and facility dismantling and removal. Equipment and materials would be salvaged, recycled, or reused, if possible. Site reclamation would include restoring the site to as near its preconstruction condition as practicable, including the recontouring of disturbed surface areas, surface *backfill*, soil buildup and reconditioning, site revegetation, site water course configuration, and erosion control, as appropriate.

2.1.3 TRANSPORTATION ACTIVITIES

Under the Proposed Action, DOE would transport spent nuclear fuel and high-level radioactive waste from commercial and DOE sites to the repository. The Naval Nuclear Propulsion Program would transport *naval spent nuclear fuel* from the Idaho National Engineering and Environmental Laboratory to the repository. Naval spent nuclear fuel is one of the DOE fuels considered in this EIS. Transportation activities would include the loading of these materials for shipment at generator sites (Section 2.1.3.1), transportation of the materials to the Yucca Mountain site using truck, rail, heavy-haul truck, or barge [see Sections 2.1.3.2 (National) and 2.1.3.3 (Nevada)], and *shipping cask* manufacturing, maintenance, and disposal (Section 2.1.3.4). Chapter 6 and Appendix J provide further discussion of transportation processes considered.

2.1.3.1 Loading Activities at Commercial and DOE Sites

This EIS evaluates the loading of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites for transportation to the proposed repository at Yucca Mountain. Activities would include preparing the spent nuclear fuel or high-level radioactive waste for delivery, loading it in a shipping cask, and placing the cask on a vehicle (see Figures 2-20 and 2-21) for shipment to the repository. This EIS assumes that at the time of shipment the spent nuclear fuel and high-level radioactive waste would be in a form that met approved acceptance and disposal criteria for the repository.

2.1.3.2 National Transportation

National transportation includes the transport of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site using existing highways (see Figure 2-22a) and railroads (see Figure 2-23a). Figures 2-22b and 23b show the representation highway and rail routes, respectively, used in the EIS analysis to estimate transportation-related impacts (see Section 6.2 for further discussion). Heavy-haul trucks could be used to transport spent nuclear fuel from commercial

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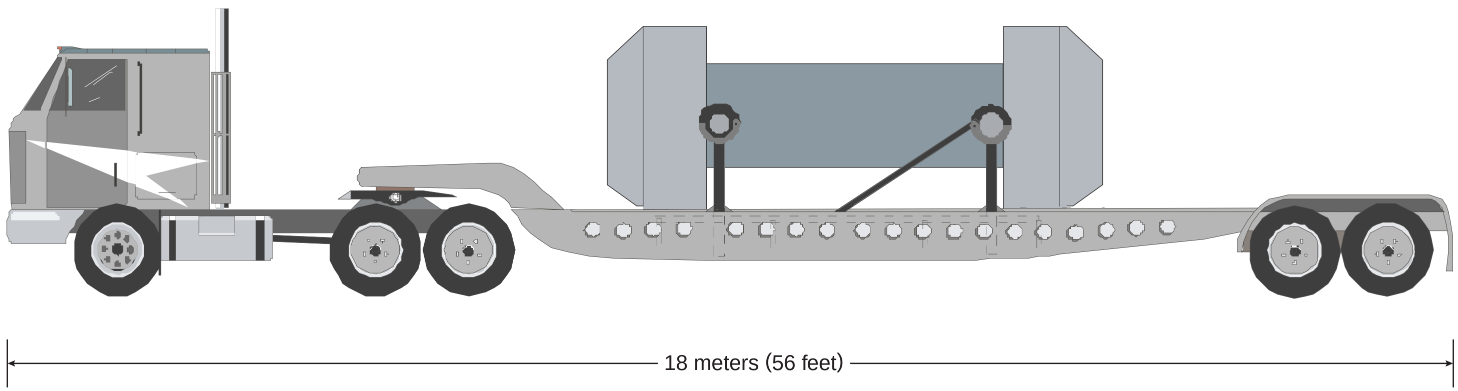
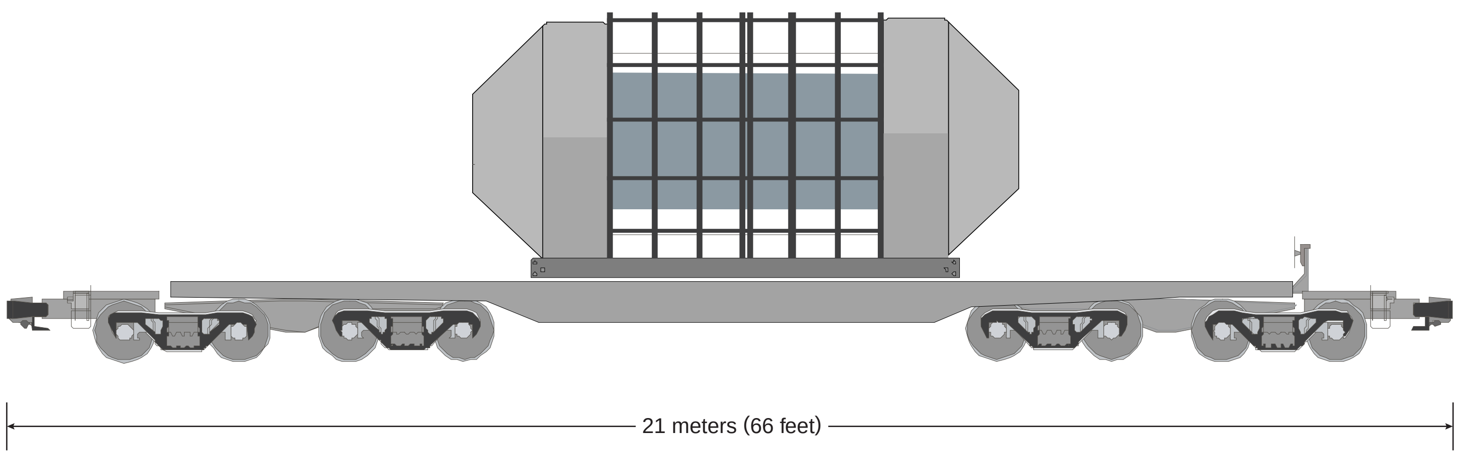


Source: DIRS 104782-Kelderhouse (1999, p. 7).

Figure 2-20. Artist's conception of a truck cask on a legal-weight tractor-trailer truck.



Source: DIRS 104782-Kelderhouse (1999, p. 8).

Figure 2-21. Artist's conception of a large rail cask on a railcar.

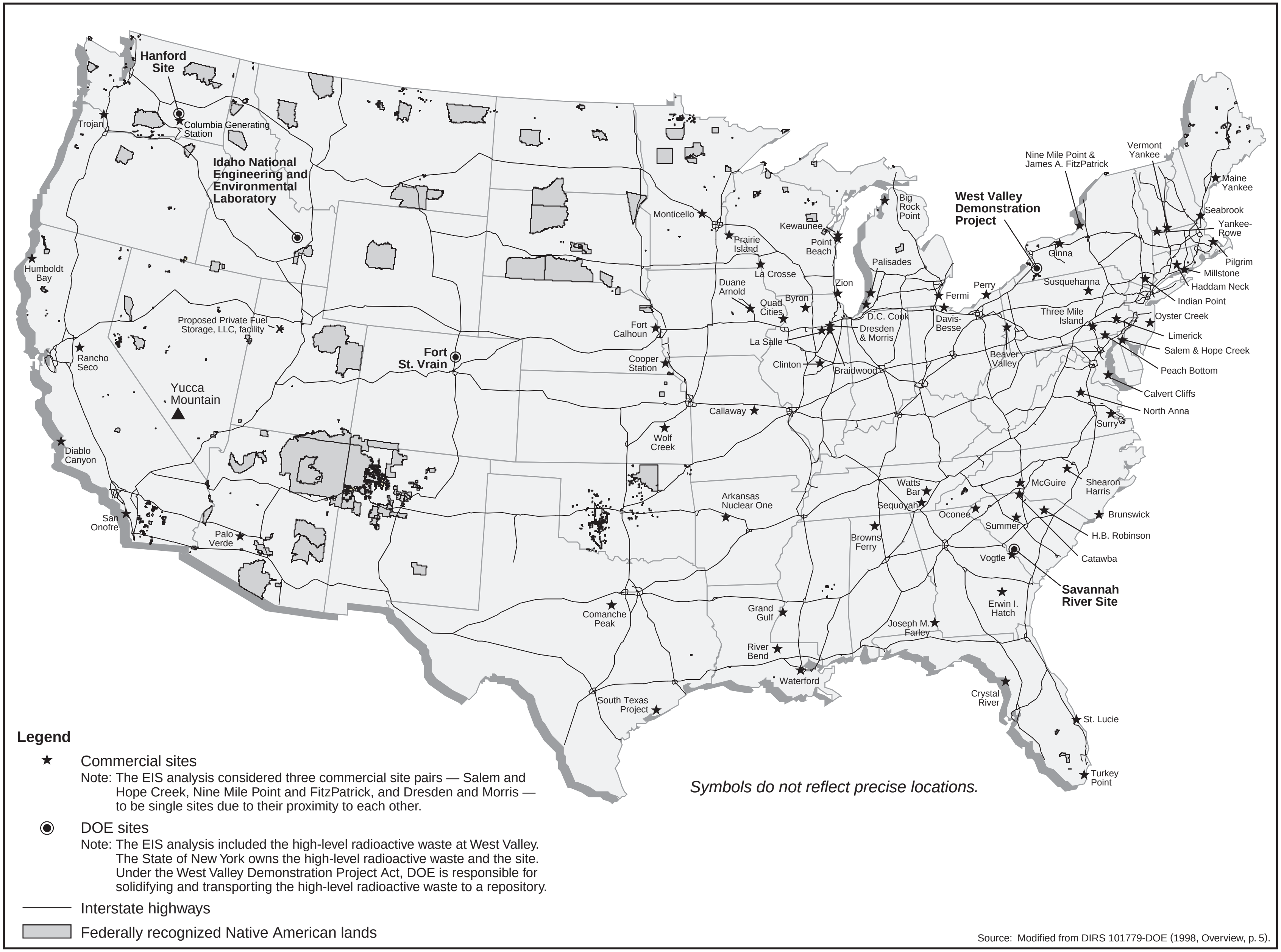


Figure 2-22a. Commercial and DOE sites and Yucca Mountain in relation to the U.S. Interstate Highway System.

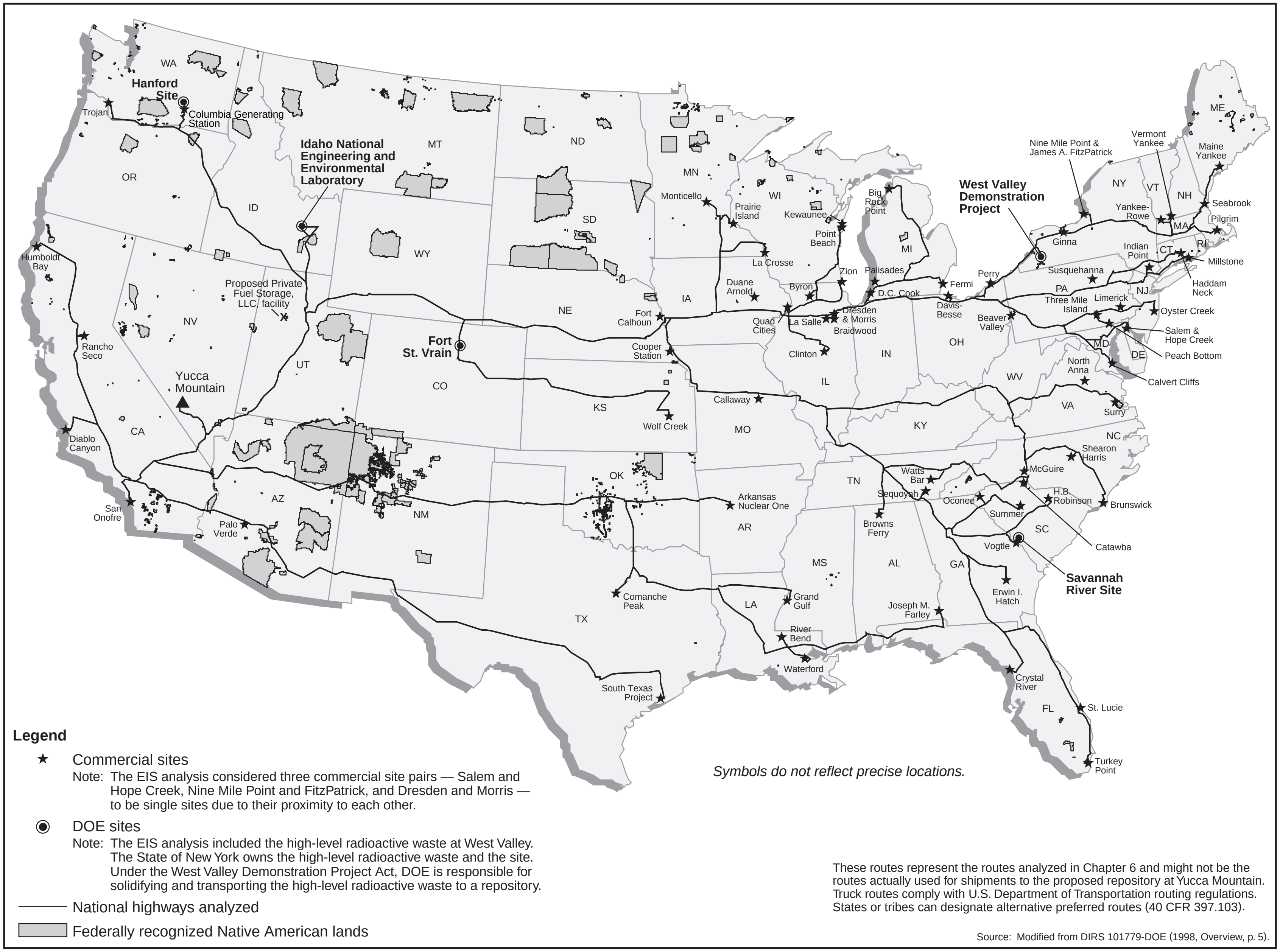


Figure 2-22b. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

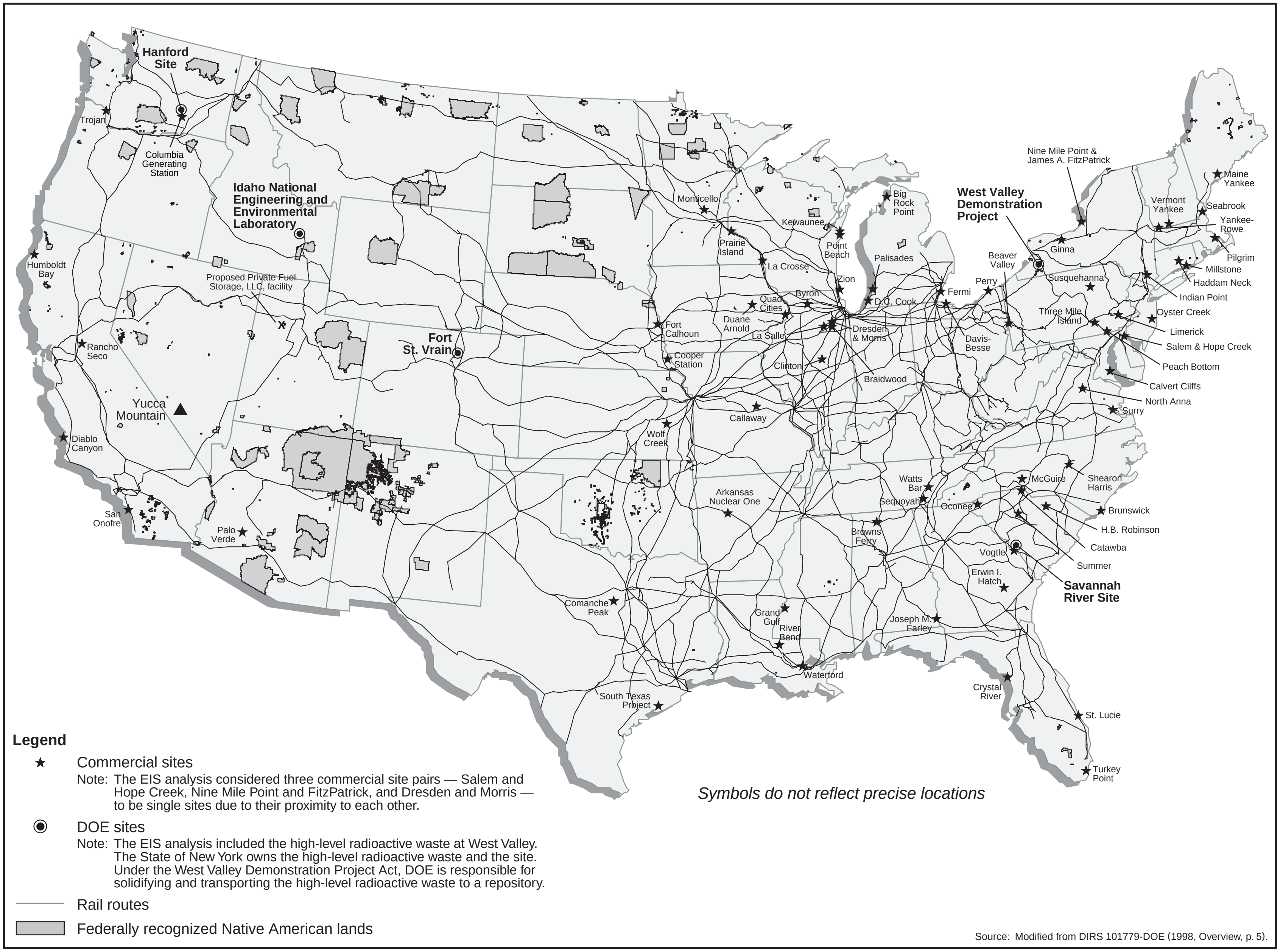


Figure 2-23a. Commercial and DOE sites and Yucca Mountain in relation to the U.S. railroad system.

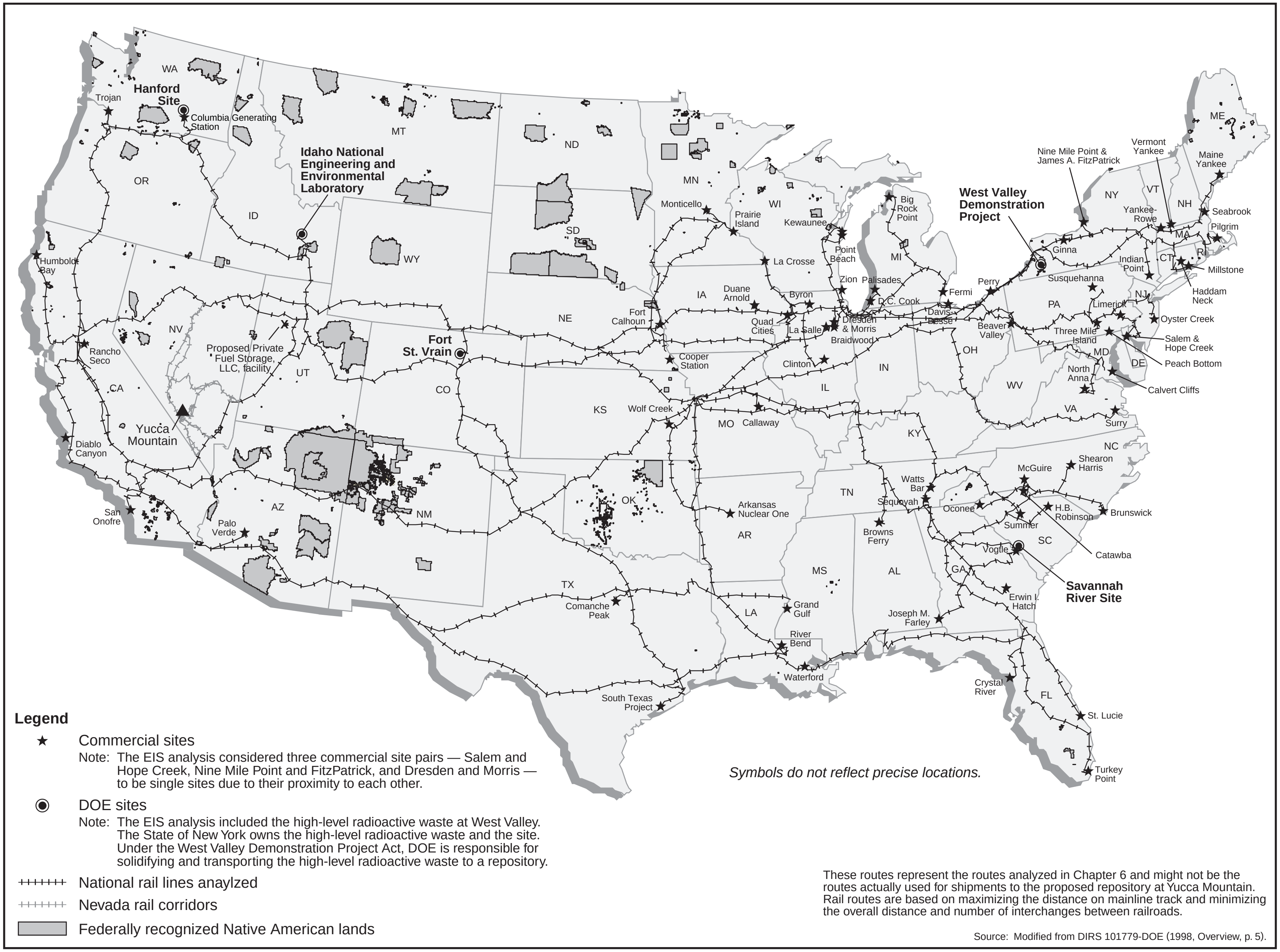


Figure 2-23b. Representative rail routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

sites that did not have rail access to a nearby rail access point. Such sites on navigable waterways could use barges to deliver spent nuclear fuel to a nearby rail access point. The transportation of spent nuclear fuel and high-level radioactive waste to the repository would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission, as well as applicable state and local regulations.

DOE would use a satellite-based transportation tracking and communications system (such as TRANSCOM), to track current truck and rail shipments of spent nuclear fuel and high-level radioactive waste to the repository. This or a similar system could provide users (for example, DOE, the Nuclear Regulatory Commission, and state and tribal governments) with information about shipments to the repository and would enable communication between the vehicle operators and a central communication station. Additional escorts are required for shipments in heavily populated areas. In these areas, armed escorts would be required for highway and rail shipments (10 CFR 73.37). The use of a satellite-based communication and tracking system, such as TRANSCOM, is subject to Nuclear Regulatory Commission approval. Under Nuclear Regulatory Commission regulations, specific information about shipments, such as time of departure and location during travel, must not be publicly disclosed and is only available to officials designated by state governors. In addition, notification and sharing of shipment information with Native American tribes is the subject of a proposed Nuclear Regulatory Commission rulemaking.

Section 180(c) of the NWPA requires DOE to provide technical and financial assistance to states and tribes for training public safety officials in jurisdictions through which it plans to transport spent nuclear fuel and high-level radioactive waste. The training is to include procedures for the safe routine transportation of these materials and for emergency response. DOE is developing the policy and procedures for implementing this assistance and has started discussions with the appropriate organizations. The Department would institute these plans before beginning shipments to the repository.

In the event of an incident involving a shipment of spent nuclear fuel or high-level radioactive waste, the transportation carrier would notify local authorities and the central communications station monitoring the shipment. DOE would make resources available to local authorities as appropriate to mitigate such an incident.

2.1.3.2.1 *National Transportation Shipping Scenarios*

DOE would ship spent nuclear fuel and high-level radioactive waste from commercial and DOE sites using some combination of the legal-weight truck, rail, heavy-haul truck, and barge modes of transport. This EIS considers two national transportation mode-mix scenarios, which for simplicity are referred to as the mostly legal-weight truck scenario and the mostly rail scenario. These scenarios encompass the broadest range of operating conditions relevant to potential impacts to human health and the environment. Table 2-3 summarizes these scenarios, and Appendix J provides additional details.

Table 2-3. National transportation scenarios (percentage based on number of shipments).[a]

Material[a]	Mostly legal-weight truck	Mostly rail
Commercial SNF	100% by legal-weight truck	About 90% by rail; about 10% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail
DOE SNF	Mostly legal-weight truck; includes about 300 naval SNF shipments from INEEL to Nevada by rail	100% by rail

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory.

sites that did not have rail access to a nearby rail access point. Such sites on navigable waterways could use barges to deliver spent nuclear fuel to a nearby rail access point. The transportation of spent nuclear fuel and high-level radioactive waste to the repository would comply with applicable regulations of the U.S. Department of Transportation and the Nuclear Regulatory Commission, as well as applicable state and local regulations.

DOE would use a satellite-based transportation tracking and communications system (such as TRANSCOM), to track current truck and rail shipments of spent nuclear fuel and high-level radioactive waste to the repository. This or a similar system could provide users (for example, DOE, the Nuclear Regulatory Commission, and state and tribal governments) with information about shipments to the repository and would enable communication between the vehicle operators and a central communication station. Additional escorts are required for shipments in heavily populated areas. In these areas, armed escorts would be required for highway and rail shipments (10 CFR 73.37). The use of a satellite-based communication and tracking system, such as TRANSCOM, is subject to Nuclear Regulatory Commission approval. Under Nuclear Regulatory Commission regulations, specific information about shipments, such as time of departure and location during travel, must not be publicly disclosed and is only available to officials designated by state governors. In addition, notification and sharing of shipment information with Native American tribes is the subject of a proposed Nuclear Regulatory Commission rulemaking.

Section 180(c) of the NWPA requires DOE to provide technical and financial assistance to states and tribes for training public safety officials in jurisdictions through which it plans to transport spent nuclear fuel and high-level radioactive waste. The training is to include procedures for the safe routine transportation of these materials and for emergency response. DOE is developing the policy and procedures for implementing this assistance and has started discussions with the appropriate organizations. The Department would institute these plans before beginning shipments to the repository.

In the event of an incident involving a shipment of spent nuclear fuel or high-level radioactive waste, the transportation carrier would notify local authorities and the central communications station monitoring the shipment. DOE would make resources available to local authorities as appropriate to mitigate such an incident.

2.1.3.2.1 *National Transportation Shipping Scenarios*

DOE would ship spent nuclear fuel and high-level radioactive waste from commercial and DOE sites using some combination of the legal-weight truck, rail, heavy-haul truck, and barge modes of transport. This EIS considers two national transportation mode-mix scenarios, which for simplicity are referred to as the mostly legal-weight truck scenario and the mostly rail scenario. These scenarios encompass the broadest range of operating conditions relevant to potential impacts to human health and the environment. Table 2-3 summarizes these scenarios, and Appendix J provides additional details.

Table 2-3. National transportation scenarios (percentage based on number of shipments).[a]

Material[a]	Mostly legal-weight truck	Mostly rail
Commercial SNF	100% by legal-weight truck	About 90% by rail; about 10% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail
DOE SNF	Mostly legal-weight truck; includes about 300 naval SNF shipments from INEEL to Nevada by rail	100% by rail

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste; INEEL = Idaho National Engineering and Environmental Laboratory.

2.1.3.2.2 *Mostly Legal-Weight Truck Shipping Scenario*

Under this scenario, DOE would ship all high-level radioactive waste and most spent nuclear fuel from commercial and DOE sites to the Yucca Mountain site by legal-weight truck. About 53,000 shipments of these materials would travel on the Nation's Interstate Highway System during a 24-year period. There would be about 41,000 commercial spent nuclear fuel shipments and about 12,000 shipments of DOE spent nuclear fuel and high-level radioactive waste. The exception would be about 300 shipments of naval spent nuclear fuel that would travel from the Idaho National Engineering and Environmental Laboratory to Nevada by rail. The Department of the Navy prepared an EIS (DIRS 101941-USN 1996, all) and issued two Records of Decision (62 *FR* 1095, January 8, 1997; 62 *FR* 23770, May 1, 1997) on its spent nuclear fuel.

Truck shipments would use Nuclear Regulatory Commission-certified, reusable shipping casks secured on legal-weight trucks (Figure 2-20). With proper labels and vehicle placards (hazard identification) and vehicle and cask inspections, a truck carrying a shipping cask of spent nuclear fuel or high-level radioactive waste would travel to the repository on highway routes selected in accordance with U.S. Department of Transportation regulations (49 CFR 397.101), which require the use of *preferred routes*. These routes include the Interstate Highway System, including beltways and bypasses. Alternative preferred routes could be designated by states and tribes following Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with affected local jurisdictions and with any other affected states.

Shipments of naval spent nuclear fuel would travel by rail in reusable rail shipping casks certified by the Nuclear Regulatory Commission. These shipments would use applicable and appropriate placards and inspection procedures.

2.1.3.2.3 *Mostly Rail Shipping Scenario*

Under this scenario, DOE would ship most spent nuclear fuel and high-level radioactive waste to Nevada by rail, with the exception of material from commercial nuclear sites that do not have the capability to load large-capacity rail shipping casks. Those sites would ship spent nuclear fuel to the repository by legal-weight truck. Commercial sites that have the capability to load large-capacity rail shipping casks but do not have immediate rail access could use heavy-haul trucks or barges to transport their spent nuclear fuel to a nearby rail line. Under this scenario, about 9,000 to 10,000 railcars of spent nuclear fuel and high-level radioactive waste would travel on the nationwide rail network over a period of 24 years. Rail shipments would consist of Nuclear Regulatory Commission-certified, reusable shipping casks secured on railcars (see Figure 2-21). In addition, there would be about 1,000 legal-weight truck shipments. All shipments would be marked with the appropriate labels and placards and would be inspected in accordance with applicable regulations.

Some of the logistics of rail transportation to the repository would depend on whether DOE used general or *dedicated freight service*. General freight shipments of spent nuclear fuel and high-level radioactive waste would be part of larger trains carrying other commodities. A number of transfers between trains could occur as a railcar traveled to the repository. The basic infrastructure and activities would be similar between general freight and dedicated trains. However, dedicated train service would contain only railcars destined for the repository. In addition to railcars carrying spent nuclear fuel or high-level radioactive waste, there would be buffer and *escort cars*, in accordance with Federal regulations. DOE would use a satellite-based system to monitor all spent nuclear fuel shipments (see Section 2.1.3.2).

TERMS RELATED TO RAIL SHIPPING

General freight rail service: A railroad freight service that handles a number of shippers and commodities. Railcars carrying spent nuclear fuel or high-level radioactive waste could switch in railyards or on sidings to a number of trains as they traveled from commercial and DOE sites to Nevada.

Dedicated freight rail service: A railroad freight service that provides exclusive service to a shipper and often involves transportation of a single commodity. Use of a separate train with its own crew carrying spent nuclear fuel or high-level radioactive waste would avoid switching railcars between trains.

Buffer cars: Railcars placed in front and in back of those carrying spent nuclear fuel or high-level radioactive waste to provide additional distance from possibly occupied railcars. Federal regulations (49 CFR 174.85) require the separation of a railcar carrying spent nuclear fuel or high-level radioactive waste from a locomotive, occupied caboose, or carload of undeveloped film by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

Escort cars: Railcars in which escort personnel (for example, security personnel) would reside on trains carrying spent nuclear fuel or high-level radioactive waste.

2.1.3.3 Nevada Transportation

Nevada transportation is part of national transportation, but the EIS discusses it separately to highlight aspects of interest to Nevada. Depending on how a shipment was transported, DOE could use one of three options or modes of transportation in Nevada to reach the Yucca Mountain site: legal-weight trucks, rail, or heavy-haul trucks. Legal-weight truck shipments arriving in Nevada would travel directly to the Yucca Mountain site. Potential routes for legal-weight truck shipments in Nevada would comply with U.S. Department of Transportation regulations (49 CFR 397.101) for selecting “preferred routes” and “delivery routes” for motor carrier shipments of highway route-controlled quantities of radioactive materials. The State of Nevada could designate alternative routes as specified in 49 CFR 397.103. Two interstate highways cross Nevada—I-80 in the north and I-15 in the south. I-15, the closest interstate highway to the proposed repository, travels through Salt Lake City, Utah, to southern California, passing through Las Vegas. Figure 2-24 shows the existing highway infrastructure in southern Nevada. The EIS analysis assumed that the proposed beltway around the urban core of Las Vegas (the Las Vegas Beltway) would be operational before 2010 and would be part of the Interstate Highway System.

Shipments arriving in Nevada by rail would travel to the repository site by rail or heavy-haul truck (legal-weight trucks could not be used due to the size and weight of the rail shipping casks). Existing rail lines in the State include two northern routes and one southern route; the Union Pacific Railroad owns both the northern and the southern routes. The northern routes pass through or near the cities of Elko, Carlin, Battle Mountain, and Reno. The southern route runs through Salt Lake City, Utah, to Barstow, California, passing through Caliente, Las Vegas, and Jean, Nevada. Figure 2-25 shows the Nevada rail infrastructure. Rail access is not currently available to the Yucca Mountain site, so DOE would have to build a branch rail line from an existing mainline railroad to the site or transfer rail casks to heavy-haul trucks at an intermodal transfer station for transport to the repository. In addition, some highways that DOE would use for heavy-haul trucks would need to be upgraded.

To indicate distinctions between available transportation options or modes in Nevada and to define the range of potential impacts associated with transportation in the State, this EIS analyzes three

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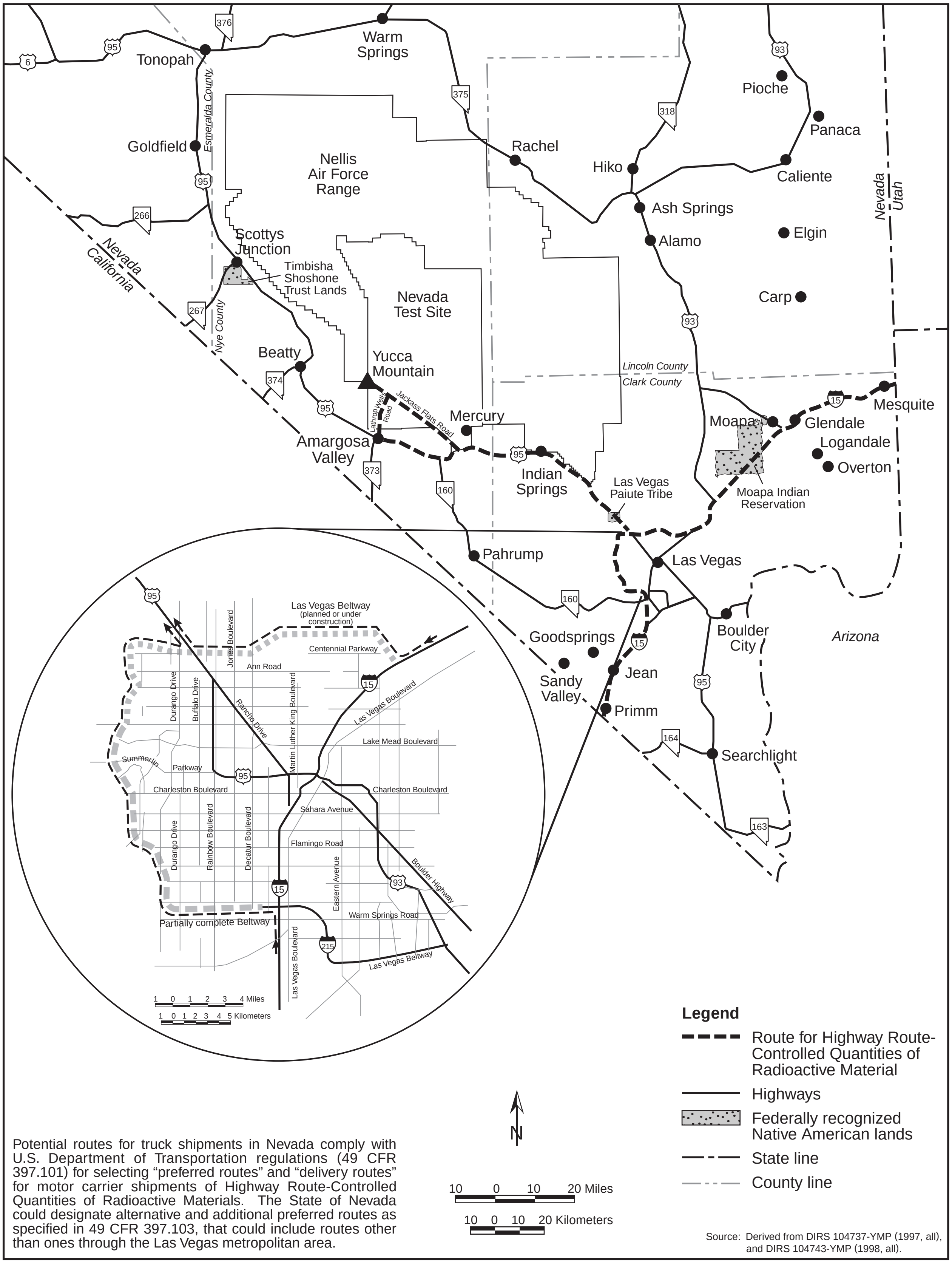

Figure 2-24. Potential Nevada routes for legal-weight truck shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

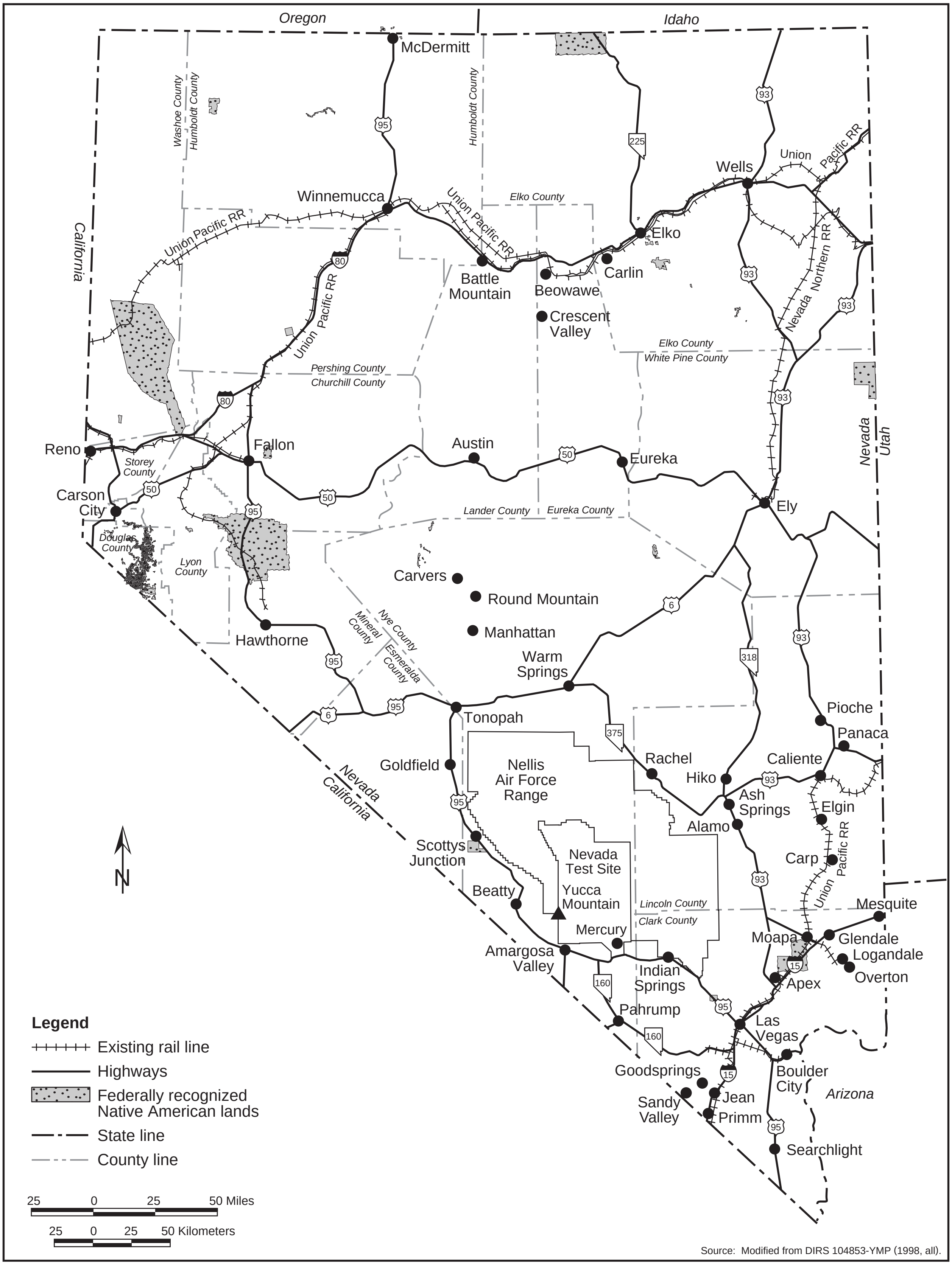

Figure 2-25. Existing Nevada rail lines.

transportation scenarios: the first, associated with the national mostly legal-weight truck scenario, is a Nevada legal-weight truck scenario; the second and third, both associated with the national mostly rail scenario, are rail transport directly to the Yucca Mountain site, and an intermodal transfer from railcar to heavy-haul truck for travel to the site. Table 2-4 summarizes the Nevada transportation scenarios.

Table 2-4. Nevada transportation shipping scenarios (percentage based on number of shipments).[a]

Material	Mostly legal-weight truck	Mostly rail	Mostly heavy-haul truck[b]
Commercial SNF	100% by legal-weight truck	About 90% by rail; about 10% by legal-weight truck	About 90% by heavy-haul truck; about 10% by legal-weight truck
HLW	100% by legal-weight truck	100% by rail	100% by heavy-haul truck
DOE SNF	Mostly by legal-weight truck; includes about 300 naval SNF shipments by rail and heavy-haul truck	100% by rail	100% by heavy-haul truck

a. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
b. Rail shipment to intermodal transfer station, and heavy-haul truck shipment from intermodal transfer station to the repository.

The following sections describe the Nevada transportation scenarios and the implementing alternatives DOE is considering for a new branch rail line or a new intermodal transfer station and associated highway route for heavy-haul trucks.

2.1.3.3.1 *Nevada Legal-Weight Truck Scenario*

Under this scenario, DOE would use legal-weight trucks in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. Naval spent nuclear fuel would be transported to Nevada by rail. In Nevada, DOE would use heavy-haul trucks to transport these 300 shipments. DOE would establish an intermodal transfer capability and an associated heavy-haul shipment capability (see Section 2.1.3.3.3).

Legal-weight truck shipments would use existing routes that satisfy regulations of the U.S. Department of Transportation for the shipment of highway route-controlled quantities of radioactive materials (49 CFR 397.101). Legal-weight trucks would enter Nevada on I-15 from the north or south, bypass the Las Vegas area on the proposed beltway, and travel north on U.S. 95 to the Nevada Test Site and then to the Yucca Mountain site (Figure 2-24).

2.1.3.3.2 *Nevada Rail Scenario*

Under this scenario, DOE would construct and operate a branch rail line in Nevada. Based on previous studies (described in Section 2.3.3.1), DOE has narrowed its consideration for a new branch rail line to five potential rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. These rail corridors are shown on Figure 2-26 and are described in the following paragraphs. DOE has analyzed a 0.4-kilometer (0.25-mile)-wide corridor for each alternative. As shown in Figure 2-26, there are possible corridor *variations*, which are described further in Appendix J.

- *Caliente Rail Corridor Implementing Alternative.* The Caliente corridor originates at an existing siding to the Union Pacific mainline railroad near Caliente, Nevada (Figure 2-26). Depending on the variations that DOE could use, the corridor is between 512 kilometers (318 miles) and 553 kilometers (331 miles) long from the Union Pacific line connection to the Yucca Mountain site.

- *Carlin Rail Corridor Implementing Alternative.* The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada (Figure 2-26). The Carlin and Caliente corridors converge near the northwest boundary of the Nellis Air Force Range (also known as the Nevada Test and Training Range). Past this point, they are identical. Depending on the variations

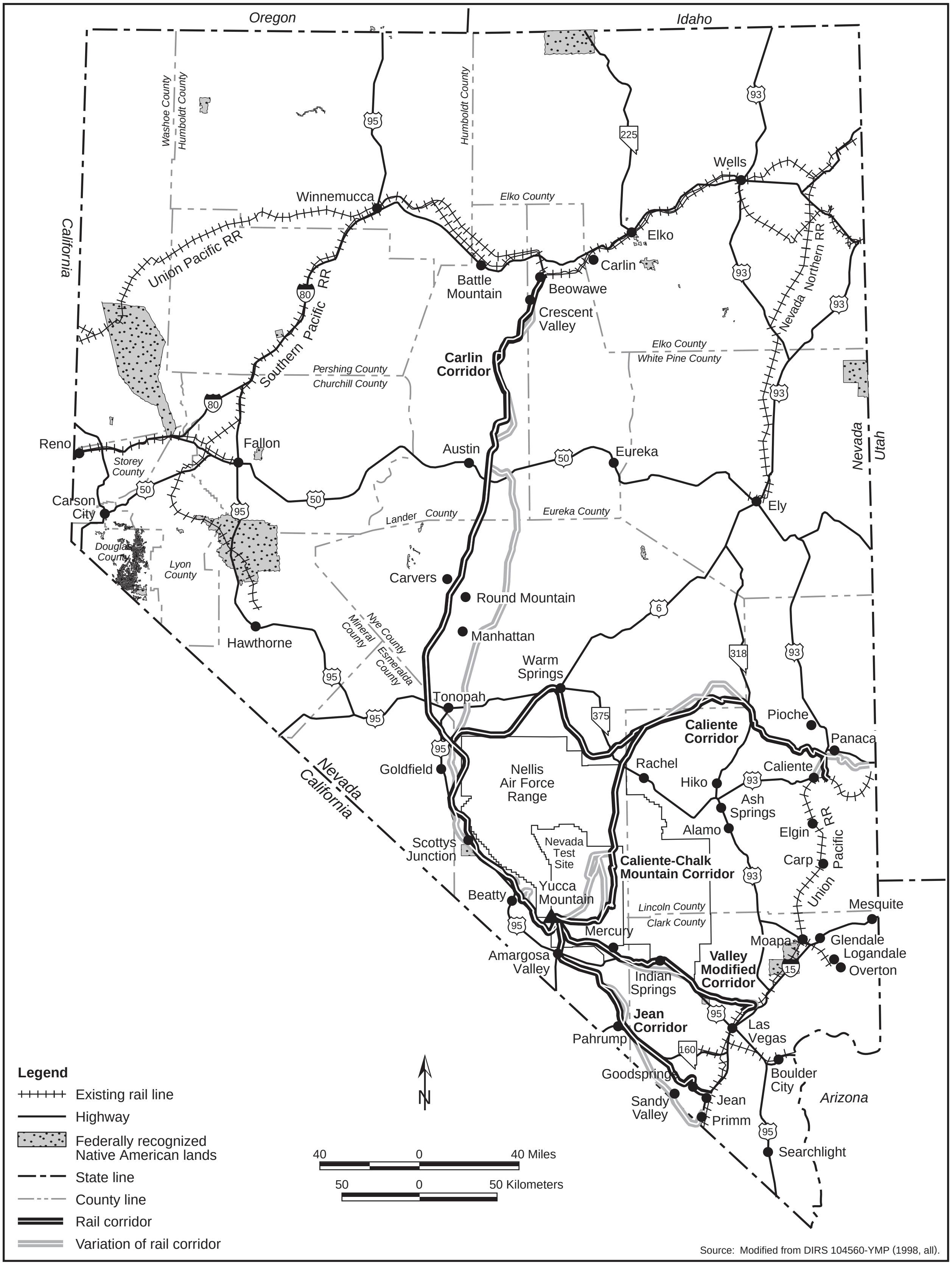

Figure 2-26. Potential Nevada rail routes to Yucca Mountain.

that DOE could use, the corridor has two major *options*—Big Smoky Valley and Monitor Valley. The Big Smoky Valley Option is between 513 kilometers (319 miles) and 529 kilometers (329 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site. Depending on the variation used, the Monitor Valley Option is between 525 kilometers (326 miles) and 544 kilometers (338 miles) long.

- *Caliente-Chalk Mountain Rail Corridor Implementing Alternative.* The Caliente-Chalk Mountain corridor is identical to the Caliente corridor until it approaches the northern boundary of the Nellis Air Force Range. At that point the Caliente-Chalk Mountain corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site (Figure 2-26). Depending on the variations that DOE could use, the corridor is between 344 kilometers (214 miles) and 382 kilometers (242 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site.

- *Jean Rail Corridor Implementing Alternative.* The Jean corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada (Figure 2-26). The corridor has two major alignment options–Wilson Pass and Stateline Pass. The Wilson Pass Option is between 181 kilometers (112 miles) and 186 kilometers (116 miles) long from the tie-in point at the Union Pacific line to the Yucca Mountain site. The Stateline Pass Option is between 198 kilometers (123 miles) and 204 kilometers (127 miles) long.

- *Valley Modified Rail Corridor Implementing Alternative.* The Valley Modified corridor originates at an existing rail siding off the Union Pacific mainline railroad northeast of Las Vegas. Depending on the variation that DOE could use, the corridor is between 157 kilometers (98 miles) and 163 kilometers (101 miles) long from the tie-in point with the Union Pacific line to the Yucca Mountain site.

2.1.3.3.2.1 Rail Line Construction. The selected rail line would be designed and built in compliance with Federal Railroad Administration safety standards. In addition, a service road along the rail line would be built and maintained. Rail line construction along any of the corridors would take between 3 and 4 years. Construction would start after the selection of a route, completion of engineering and environmental studies related to alignment within the related corridor, completion of the rail line design, and land acquisition.

Construction activities would include the development of *construction support areas*; construction of access roads to the rail line construction initiation points and to major structures to be built, such as bridges; and movement of equipment to the construction initiation points. The number and location of construction initiation points would be based on such variables as the route selected, the length of the line, the construction schedule, the number of contractors used for construction, the number of structures to be built, and the locations of existing access roads adjacent to the rail line.

The construction of a rail line would require the clearing and excavation of previously undisturbed lands in the corridor and the establishment of borrow and *spoils areas* outside the corridor. To establish a stable platform for the rail track, construction crews would excavate some areas and fill (add more soil to) others, as determined by terrain features. To the extent possible, material excavated from one area would be used in areas that required fill material. However, if the distance to an area requiring fill material was excessive, the excavated material would be disposed of in adjacent low areas, and a *borrow area* would be established adjacent to the area requiring fill material. Access roads to spoils and borrow areas would be built during the track platform construction work.

Typical heavy-duty construction equipment (front-end loaders, power shovels, and other diesel-powered support equipment) would be used for clearing and excavation work. Trucks would spray water along graded areas for dust control and soil compaction. The fill material used along the rail line to establish a stable platform for the track would be compacted to meet design requirements. Water could be shipped from other locations or obtained from wells drilled along the route.

Railroad track construction would consist of the placement of railbed material, ties, rail, and ballast (support and stabilizing materials for the rail ties) over the completed railbed platform. Other activities would include the following:

- Installation of at-grade crossings (which would require rerouting existing utility lines in some areas)
- Installation of fences along the rail line, if requested by other agencies (for example, the Bureau of Land Management or the Fish and Wildlife Service)
- Installation of the train control system (monitoring equipment, signals, communications equipment)
- Final grading of slopes, installation of rock-fall protection devices, replacement of topsoil, revegetation and installation of other permanent erosion control systems, and completion of the adjacent maintenance road

2.1.3.3.2.2 Rail Line Operations. Branch rail line operations from the junction with the main line to the proposed repository at Yucca Mountain would meet Federal Railroad Administration standards for maintenance, operations, and safety. Current plans for the branch rail line anticipate a train with two 3,000-horsepower, diesel-electric locomotives; from one to five railcars containing spent nuclear fuel and high-level radioactive waste; *buffer cars*; and escort cars. Trains could also haul other freight to and from the repository site, thereby decreasing the truck traffic on local roads. The EIS analyses assumed that all repository construction materials and equipment would be transported to the Yucca Mountain site by truck.

The operational interface between the Union Pacific and the branch rail line would be determined by whether the waste was shipped to Nevada by dedicated rail service or by *general freight rail service*. With dedicated rail or general freight service to Nevada, the railcars carrying spent nuclear fuel or high-level radioactive waste could be parked on a side track (off the main rail line) at the connection point until a train could be assembled to travel to the repository site. A small secure railyard off the main rail line would be established for switching operations. Railcars with spent nuclear fuel or high-level radioactive waste would have to be moved within 48 hours in accordance with U.S. Department of Transportation regulations (49 CFR 174.14).

This EIS assumes there would be about four trains per week for shipments of spent nuclear fuel and high-level radioactive waste to the repository. In addition, the rail line would enable the transport of other material to the repository, including empty disposal containers, bulk concrete materials, steel, large equipment, and general building materials. The EIS assumes one train per week for this other material for a total of about five trains per week to the repository from about 2010 to 2033.

2.1.3.3.3 *Nevada Heavy-Haul Truck Scenario*

Under this scenario, rail shipments to Nevada would go to an intermodal transfer station where shipping casks would transfer from railcars to heavy-haul trucks. The heavy-haul trucks would travel on existing roads to the repository, once the roads were appropriately upgraded. The following sections describe the implementing alternatives (the intermodal transfer station locations and associated highway routes for heavy-haul trucks) that the EIS analyzes.

2.1.3.3.3.1 Intermodal Transfer Stations. To enable intermodal transfers and heavy-haul shipments to the repository, an intermodal transfer station would be built and operated in Nevada. DOE stable platform for the track would be compacted to meet design requirements. Water could be shipped from other locations or obtained from wells drilled along the route.

Railroad track construction would consist of the placement of railbed material, ties, rail, and ballast (support and stabilizing materials for the rail ties) over the completed railbed platform. Other activities would include the following:

- Installation of at-grade crossings (which would require rerouting existing utility lines in some areas)
- Installation of fences along the rail line, if requested by other agencies (for example, the Bureau of Land Management or the Fish and Wildlife Service)
- Installation of the train control system (monitoring equipment, signals, communications equipment)
- Final grading of slopes, installation of rock-fall protection devices, replacement of topsoil, revegetation and installation of other permanent erosion control systems, and completion of the adjacent maintenance road

2.1.3.3.2.2 Rail Line Operations. Branch rail line operations from the junction with the main line to the proposed repository at Yucca Mountain would meet Federal Railroad Administration standards for maintenance, operations, and safety. Current plans for the branch rail line anticipate a train with two 3,000-horsepower, diesel-electric locomotives; from one to five railcars containing spent nuclear fuel and high-level radioactive waste; *buffer cars*; and escort cars. Trains could also haul other freight to and from the repository site, thereby decreasing the truck traffic on local roads. The EIS analyses assumed that all repository construction materials and equipment would be transported to the Yucca Mountain site by truck.

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This EIS assumes there would be about four trains per week for shipments of spent nuclear fuel and high-level radioactive waste to the repository. In addition, the rail line would enable the transport of other material to the repository, including empty disposal containers, bulk concrete materials, steel, large equipment, and general building materials. The EIS assumes one train per week for this other material for a total of about five trains per week to the repository from about 2010 to 2033.

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2.1.3.3.3.1 Intermodal Transfer Stations. To enable intermodal transfers and heavy-haul shipments to the repository, an intermodal transfer station would be built and operated in Nevada. DOE is considering three potential locations for intermodal transfer operations: near Caliente, northeast of Las Vegas (Apex/Dry Lake), and southwest of Las Vegas (Sloan/Jean) (Figure 2-27). DOE has identified general areas at these three locations where it could build and operate an intermodal transfer station:

- *Caliente Intermodal Transfer Station Implementing Alternative*. The Caliente siting areas are south of Caliente in the Meadow Valley Wash. DOE has identified two possible areas along the west side of the wash.

- *Apex/Dry Lake Intermodal Transfer Station Implementing Alternative*. The areas for a potential station are northeast of Las Vegas along the Union Pacific Railroad's main line at Dry Lake and Apex. Three areas are available for intermodal transfer station siting. The first area is directly adjacent to the Dry Lake siding along the west side of the Union Pacific line. The second area is smaller and lies on the same side of the tracks a short distance northeast of the first area. The third area is between Interstate 15 and the Union Pacific tracks south of where the tracks cross the Interstate. Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary.

- *Sloan/Jean Intermodal Transfer Station Implementing Alternative*. The potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific rail sidings at Sloan and Jean. One area is on the west side of I-15, north of the Union Pacific rail underpass at I-15. The second is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15.

The intermodal transfer station would be a fenced area of about 250 meters (820 feet) by 250 meters and a rail siding that would be about 2 kilometers (1.2 miles) long (see Figure 2-28). The estimated total area occupied by the facility and support areas would be about 0.2 square kilometer (50 acres). It would include rail tracks, two shipping cask transfer cranes (one on a gantry rail, and one on a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connection tracks to the existing Union Pacific line and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. Construction of an intermodal transfer station would take an estimated 1.5 years.

Trains would switch from the main Union Pacific track to an existing or newly constructed passing track. The railcars carrying casks of spent nuclear fuel or high-level radioactive waste would be uncoupled from the train and switched to the intermodal transfer station track. The train would return to the main Union Pacific line. A railyard locomotive would move the cars containing the casks to the station.

The loading and unloading process would begin with the return of a heavy-haul truck from the repository. The empty cask returning from the repository would be lifted from the truck, loaded on an empty railcar, and secured. The gantry or mobile crane would then remove a loaded cask from another railcar and transfer it to the same truck, where it would be secured and inspected before shipment to the repository.

The station would accept railcars as they arrived (24 hours a day, 7 days a week), but it would normally dispatch heavy-haul trucks during early morning daylight hours on weekdays, consistent with current Nevada heavy-haul shipment practices.

Intermodal transfer station operations would not depend on whether the railcars that carried spent nuclear fuel and high-level radioactive waste arrived on dedicated or general freight trains.

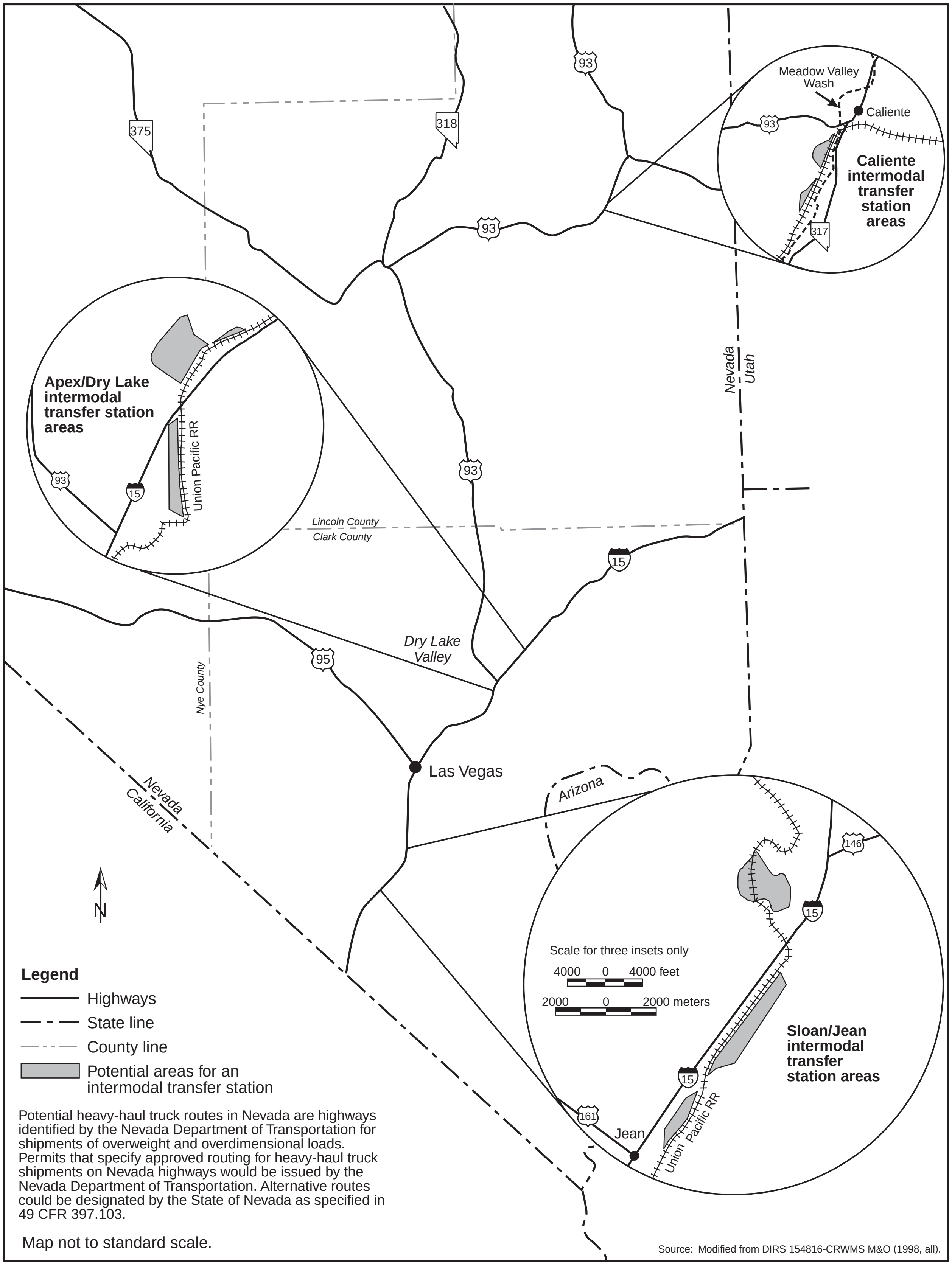


Figure 2-27. Potential intermodal transfer station locations.

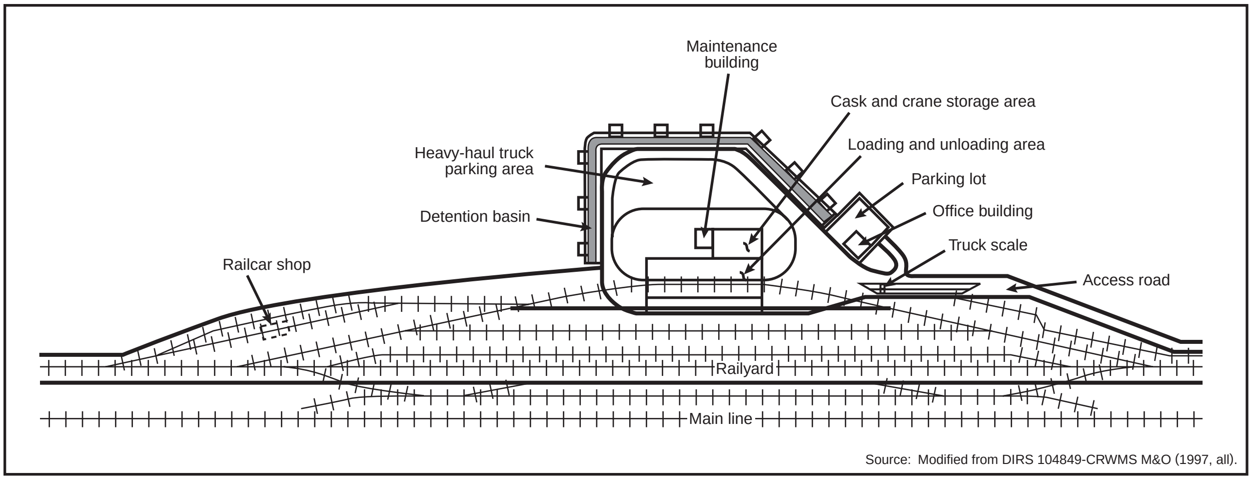


Figure 2-28. Conceptual diagram of intermodal transfer station layout.

At the completion of the 24 years of shipping, the intermodal transfer station would be decommissioned and, if possible, reused.

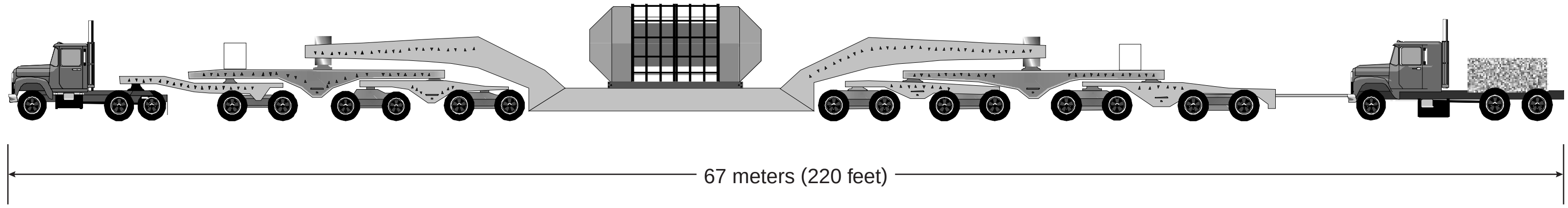
2.1.3.3.3.2 Highway Routes for Heavy-Haul Shipments. Figure 2-29 is an illustration of a heavy-haul truck that DOE could use to transport spent nuclear fuel and high-level radioactive waste to the repository. The heavy-haul truck would weigh about 91,000 kilograms (200,000 pounds) unloaded and would be up to 67 meters (220 feet) long. It would be custom-built for repository shipments. Typical range of open-road speeds would be 32 to 80 kilometers (20 to 50 miles) per hour.

Heavy-haul truck shipments from an intermodal transfer station to the repository would comply with U.S. Department of Transportation requirements for shipments of highway route-controlled quantities of radioactive materials (49 CFR Part 177) and with State of Nevada permit requirements for heavy-haul shipments. Nevada permits heavy-haul shipments on Monday through Friday (excluding holidays) but only in daylight hours.

Road upgrades for candidate routes, if necessary, would involve four kinds of construction activities: (1) widening the shoulders and constructing turnouts and truck lanes, (2) upgrading intersections that are inadequate for heavy-haul truck traffic, (3) increasing the asphalt thickness (overlay) of some sections, and (4) upgrading engineered structures such as culverts and bridges. The overlay work would include upgrades needed to remove frost restrictions from some road sections.

Shoulder widening and the construction of turnouts and truck lanes would occur as needed along the side of the existing pavement. Shoulders would be widened from 0.33 or 0.66 meter (1 or 2 feet) to 1.2 meters (4 feet). Widening would build the existing shoulder up to pavement height. Truck lanes would be built on roadways with grades exceeding 4 percent. Turnout lanes would be built approximately every 8 to 32 kilometers (5 to 20 miles) depending on projected traffic. The truck lanes and turnouts would require land clearing and soil excavation or fill to establish the roadway. Culverts under the roadway would be lengthened. DOE assumes that most borrow material for construction could come from existing Nevada Department of Transportation borrow areas. Asphalt could be produced at a portable plant in the borrow areas. Appendix J contains descriptions of the specific highway improvements for the five routes.

The following paragraphs describe the potential highway routes for heavy-haul trucks DOE is considering for the intermodal transfer station location and unique operational considerations for each route.



Source: DIRS 104782-Kelderhouse (1999, p. 2).

Figure 2-29. Artisit's conception of a heavy-haul truck carrying a rail shipping cask.

- *Caliente Intermodal Transfer Station Highway Routes*. Heavy-haul trucks leaving the Caliente intermodal transfer station could travel on one of three potential routes: (1) Caliente, (2) Caliente/ Chalk Mountain, and (3) Caliente/Las Vegas (see Figure 2-30).

  The Caliente route would be approximately 533 kilometers (331 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. Highway 6. The trucks would continue on U.S. 6 to the intersection with U.S. 95 in Tonopah, then into Beatty on U.S. 95, where an *alternate* truck route would be built because the existing intersection is too constricted to allow a turn. Heavy-haul trucks would then travel south on U.S. 95 to the Lathrop Wells Road exit, which accesses the Yucca Mountain site. Because of the estimated travel time associated with the Caliente route and the restriction on nighttime travel for heavy-haul vehicles, DOE would construct a parking area along the route to enable these vehicles to park overnight. This parking area would be near the U.S. 6 and U.S. 95 interchange at Tonopah.

  The Caliente/Chalk Mountain route would be approximately 282 kilometers (175 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, on State Route 375 to Rachel, and head south through the Nellis Air Force Range to the Nevada Test Site.

  The Caliente/Las Vegas route would be approximately 376 kilometers (234 miles) long. Heavy-haul trucks leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15, northeast of Las Vegas. The trucks would travel south on I-15 to the exit for the proposed northern Las Vegas Beltway, then would travel west on the beltway. They would leave the beltway at U.S. 95, and head north on U.S. 95 to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

- *Apex/Dry Lake Intermodal Transfer Station Highway Route*. Heavy-haul trucks would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway, and would travel west on the beltway. The trucks would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Nevada Test Site. They would then travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. This route is about 183 kilometers (114 miles) long (see Figure 2-30).

- *Sloan/Jean Intermodal Transfer Station Highway Route*. Heavy-haul trucks leaving a Sloan/ Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel to the Nevada Test Site. They would then travel on Jackass Flats Road to the Yucca Mountain site. This route would be approximately 190 kilometers (118 miles) long (see Figure 2-30).

2.1.3.4 Shipping Cask Manufacturing, Maintenance, and Disposal

To transport spent nuclear fuel and high-level radioactive waste to the repository, DOE would use existing or new shipping casks that met Nuclear Regulatory Commission regulations (10 CFR Part 71). One or more qualified companies that provide specialized metal structures, tanks, and other heavy equipment would manufacture new shipping casks. The number and type of shipping casks required would depend on the predominant mode of transportation.

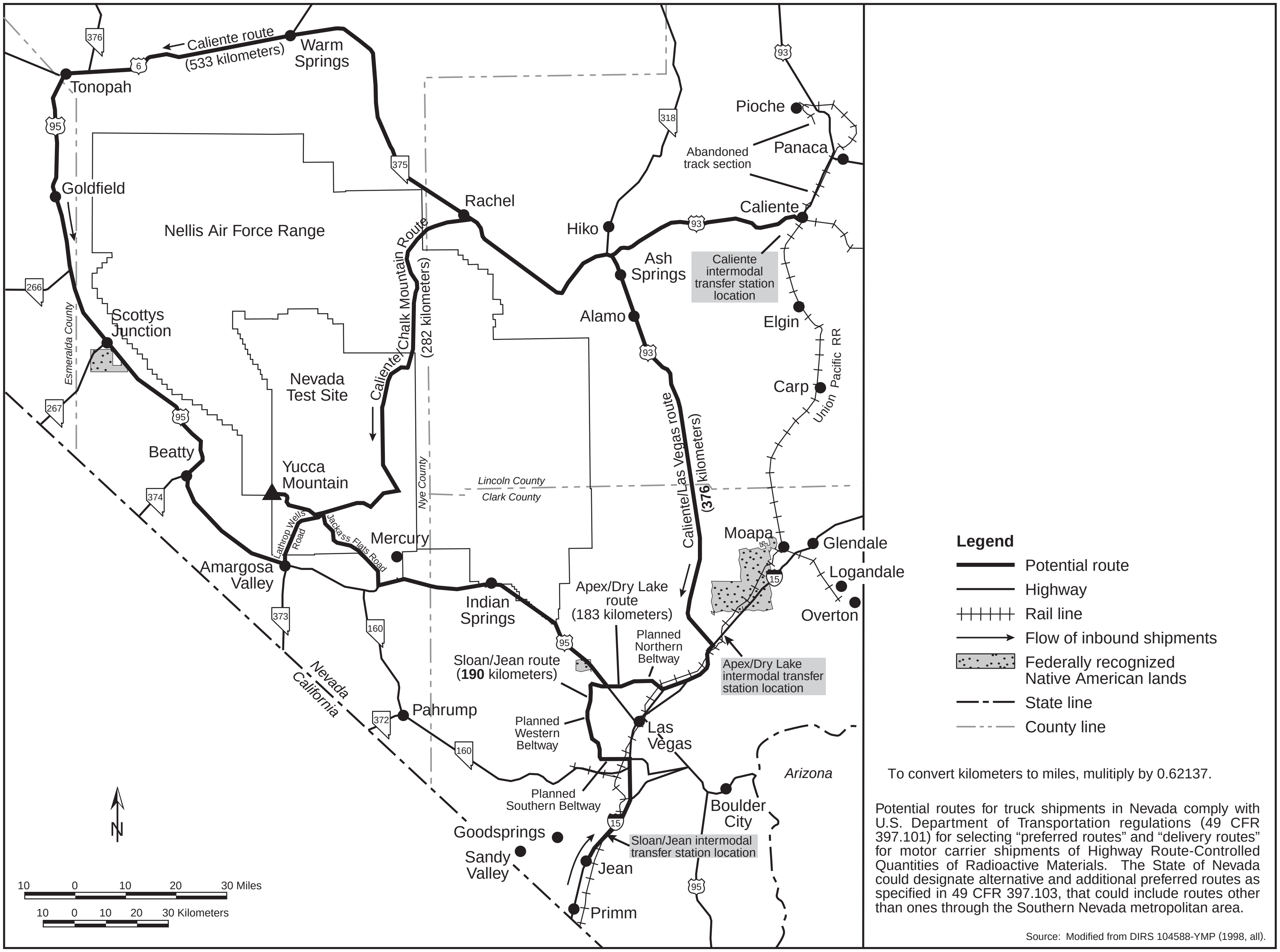


Figure 2-30. Potential routes in Nevada for heavy-haul trucks.

DOE would remove casks from service periodically for maintenance and inspection. These activities would occur at a cask maintenance facility(s) where cask functions and components would be checked and inspected in compliance with Nuclear Regulatory Commission requirements and preventive maintenance procedures. The major operations involved in cask maintenance would include decontamination, replacement of limited-life components such as O-rings, and verification of radiation *shielding* integrity, structural integrity, and heat transfer efficiency.

The large number of repository shipments would require new facilities for cask maintenance. DOE has not decided where in the United States it would locate a cask maintenance facility(s), but this EIS assumes that such a facility would be at the repository inside the Restricted Area at the North Portal on approximately 0.01 square kilometer (2.5 acres). Minor cask maintenance activities could occur at commercial or DOE sites.

2.1.4 ALTERNATIVE DESIGN CONCEPTS AND DESIGN FEATURES

DOE used the preliminary design concept in the *Viability Assessment of a Repository at Yucca Mountain* (DIRS 101779-DOE 1998, all), referred to as the Viability Assessment reference design, to evaluate impacts in the Draft EIS. While it was preparing the Draft EIS, DOE considered a broad range of design features and alternatives that would enhance the VA reference design within the License Application Design Selection process (DIRS 107292-CRWMS M&O 1999, all). In addition, the features and alternatives were combined into groups called *enhanced design alternatives*, each of which defined a unique design concept for the repository. DOE anticipated choosing an enhanced design alternative that it could carry forward to the licensing process.

The final *License Application Design Selection Report* (DIRS 107292-CRWMS M&O 1999, all) recommended Enhanced *Design Alternative* II (EDA II) to carry forward in the design evolution. However, DOE did specify that backfill should be only a possible option in EDA II. Accordingly, DOE adopted EDA II without backfill as the design to be evaluated for the purpose of making a determination on site recommendation, as documented in the Science and Engineering Report (DIRS 153849-DOE 2001, all). EDA II without backfill, over a range of thermal operating modes, was evaluated in the Supplement to the Draft EIS and is also the basis for this Final EIS.

The following section qualitatively discusses potential future design features and alternatives. Appendix E provides further detail on alternative design concepts and alternatives and their potential environmental impacts.

2.1.4.1 Design Features and Alternatives To Control the Thermal/Moisture Environment in the Repository and To Limit Release and Transport of Radionuclides

Through successive evaluations and improvements, the repository design has evolved to the flexible design. This represents the current state of the ongoing process that identifies and develops ideas through conceptual, then preliminary, then more detailed designs to produce a design that DOE would use for purposes of the Secretary of Energy’s determination of whether to recommend approval of the Yucca Mountain site to the President for development of a geologic repository. Coupled with information from ongoing scientific tests and investigations, the design process continues to provide insights into how to improve repository performance and reduce uncertainties in performance projections.

A key to the determination on site recommendation is demonstrating whether a repository at Yucca Mountain would be likely to meet regulatory standards. To that end, scientific tests and studies identify and quantify uncertainties in performance assessment and confirm performance projections. Due to limitations in the understanding of natural processes that might occur over thousands of years, as well as the limits on being able to characterize the site fully, uncertainties in performance assessments can never

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A key to the determination on site recommendation is demonstrating whether a repository at Yucca Mountain would be likely to meet regulatory standards. To that end, scientific tests and studies identify and quantify uncertainties in performance assessment and confirm performance projections. Due to limitations in the understanding of natural processes that might occur over thousands of years, as well as the limits on being able to characterize the site fully, uncertainties in performance assessments can never be completely eliminated. DOE believes that the natural system and the robust flexible design would accommodate unquantified and residual uncertainties through performance margin (design and safety) and defense-in-depth. *Defense-in-depth* is a design approach that relies on a series of barriers, both natural and manmade, that would work in a complementary manner to minimize the amount of radioactive material that could eventually travel from the repository to the human environment.

Refining details of the design of the proposed repository is an ongoing and progressive process [see the Science and Engineering Report (DIRS 153849-DOE 2001, Section 2.1.2)]. As more information becomes available about the site, along with results from tests to evaluate the implementation of the design, DOE will continue to refine the repository design. To increase the level of confidence in the understanding of long-term repository behavior, scientific tests would continue throughout the periods before and during License Application (if the site was recommended and approved for development as a repository), construction authorization, repository operations, and performance monitoring. With the flexibility inherent in the design, periodic reviews of the results of the ongoing testing program and other design activities could prompt further design feature modifications.

As described in this chapter, DOE is considering a number of scenarios and operating modes, which are defined by key parameters that include the number of waste packages, spacing between waste packages, whether there would be surface aging, average linear thermal load, average maximum waste package temperature, emplacement period, emplacement area, length of emplacement and access drifts (as well as total excavated volume), drift spacing, and ventilation (forced-air and natural).

As an example of ongoing studies, DOE is examining the use of an extended period of natural ventilation of emplacement drifts after a period of forced-air ventilation. The heat generated by the spent nuclear fuel and high-level radioactive waste could develop and maintain a temperature difference to drive passive ventilation of the emplacement drifts throughout the maximum time the repository would remain open. The heat from the waste could be used to draw cooler, drier external air through the intake shafts, across the emplacement drifts, and out the exhaust shafts (located at an elevation above the intakes), much the way heat from a fireplace draws air from a room and exhausts it through a chimney. Passive ventilation is used to regulate air temperature in buildings and has similar uses in large subsurface structures such as mines. Findings in numerous caves that are analogous to a deep geologic repository (DIRS 153849-DOE 2001, Section 2.1.5.4) support the idea that the environment of a naturally ventilated underground system could, under certain conditions, preserve materials for several thousand years and could greatly reduce waste package degradation. Optimizing the repository design to accommodate natural ventilation could result in a reconfigured supply and exhaust scheme, additional shafts, and air control devices for the drifts. Changes at the surface would include additional Ventilation Shaft Operations Areas associated with ventilation and exhaust shafts, as well as access roads to the additional shaft locations.

Drift spacing could be greater or smaller than that presented for the analytical scenarios, and could influence the size of the emplacement area and the length of emplacement and access drifts, as well as the total excavated underground volume (see DIRS 153849-DOE 2001, Section 2.1.4). Drift spacing versus waste package spacing is a design trade-off to achieve lower heat output per unit volume of a repository. The effect of drift spacing on these related parameters would be less than the effect of waste package spacing in the analytical scenarios discussed in this EIS. Therefore, DOE did not perform a *quantitative* evaluation of the environmental impacts of variable drift spacing.

2.1.4.2 Design Features and Alternatives to Support Operational and Cost Considerations

Uncertainties in future funding profiles or the order of spent nuclear fuel or high-level radioactive waste shipments could result in development of the repository in a sequential or modular manner (that is, constructing the surface and subsurface facilities in portions, or “modules”). This approach would facilitate the ability to incorporate “lessons learned” from initial work into subsequent modules, reduce initial construction costs and investment risk, and potentially increase confidence in meeting the schedule for waste receipt and emplacement. DOE has requested that the National Research Council continue the study of possible repository development strategies (DIRS 153849-DOE 2001, Section 2.1.3).

2.1.5 ESTIMATED COSTS ASSOCIATED WITH THE PROPOSED ACTION

DOE has estimated the total cost of the Proposed Action to construct, operate and monitor, and close a geologic repository at Yucca Mountain, including the transportation of spent nuclear fuel and high-level radioactive waste to the repository (DIRS 156900-DOE 2001, all). The estimate is based on acceptance and disposal of about 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). Table 2-5 lists the estimated costs. The total future costs from 2002 to closure for the flexible design would range from about $42.7 to $57.3 billion (in 2001 dollars). DOE is reporting future costs for comparison with the No-Action Alternative. Historical costs through 2001 are $8.8 billion (in 2001 dollars). The costs are representative and would vary somewhat, depending on the operating mode, packaging and transportation scenarios, and the Nevada transportation implementing alternative selected.

Table 2-5. Proposed Action costs from 2002 to closure.[a,b]

Description	Operating mode	
	Higher-temperature	Lower-temperature
Monitored geologic repository	31.5	37.4 - 43.1
Waste acceptance, storage, and transportation	4.3	4.3
Nevada transportation	0.8	0.8
Program integration	2.2	2.4 - 3.7
Institutional	3.9	4.1 - 5.4
Total	***$42.7***	***$49.0 - 57.3***

a. Source: DIRS 156900-DOE (2001, all).
b. Adjusted to 2001 dollars, in billions per DIRS 156899-DOE (2001, Appendix A).

The activities comprising the cost elements, Monitored Geologic Repository; Waste Acceptance, Storage and Transportation; and Nevada Transportation in Table 2-5 are described in this EIS. The last two elements are Program Integration and Institutional. Program Integration includes Quality Assurance (which is a mandatory program to identify and ensure implementation of requirements that protect the health and safety of the public, workers, and environment), Program Management and Integration, and non-Office of Civilian Radioactive Waste Management costs associated with the NRC, Nuclear Waste Technical Review Board, and the Nuclear Waste Negotiator. Institutional includes financial assistance for transportation planning. Details about the estimated costs are in *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program* (DIRS 153255-DOE 2001, all) and *Life Cycle Cost Analysis for Repository Flexible Design Concepts* (DIRS 156900-DOE 2001, all). These reports provide further information on the basis of the estimates, time phasing of the expected expenditures, and the subdivision of the costs between the major activities noted in Table 2-5. For example, the cost to engineer and construct the repository would be approximately equivalent to the estimated program costs from 2002 to 2010 (proposed repository opening), or $8.3 to $9.1 billion (in 2001 dollars).

The most recent estimates show that approximately 70 percent of the repository-related costs would be paid from the Nuclear Waste Fund (fees collected by nuclear utilities from ratepayers) and about 30 percent from taxpayer revenues (primarily to pay for disposal of DOE spent nuclear fuel and high-level radioactive waste).

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2.2 No-Action Alternative

This section describes the No-Action Alternative, which provides a basis for comparison with the Proposed Action. Under the No-Action Alternative, and consistent with the Nuclear Waste Policy Act, as amended [Section 113(c)(3) (the EIS refers to the amended Act as the NWPA)], DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. Commercial nuclear power utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States (see Figure 2-31).

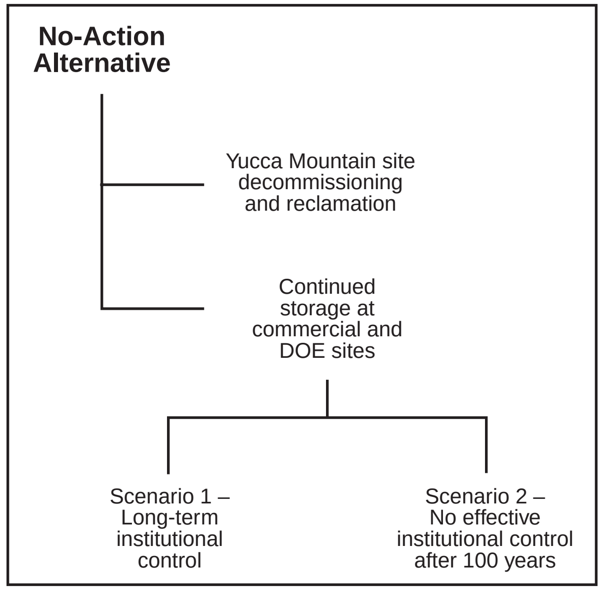


Figure 2-31. No-Action Alternative activities and analytical scenarios.

In addition, DOE would prepare a report to Congress with the Department's recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. Under any future course that would include continued storage at the generator sites, commercial utilities and DOE would have to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment. However, the future course that Congress, DOE, and the commercial utilities would take if Yucca Mountain were not recommended as a repository remains uncertain. DOE recognizes that a number of possibilities could be pursued, including continued storage of spent nuclear fuel and high-level radioactive waste at one or more centralized locations, study and selection of another location for a deep geologic repository (Chapter 1 identifies the process and alternative sites previously selected by DOE for technical study as potential geologic repository locations), the development of new technologies (for example, transmutation), or reconsideration of alternatives to geologic disposal. The environmental considerations of these possibilities have been analyzed in other contexts in other documents to varying degrees.

The No-Action Alternative did not consider redistribution or centralizing of spent nuclear fuel. However, Table 7-1 lists several references to documents that have evaluated potential environmental impacts of away-from-reactor spent nuclear fuel consolidation facilities. In addition, because the Department believes that it is a reasonably foreseeable future action, the Final EIS includes an evaluation of potential cumulative transportation impacts associated with the shipment of 40,000 metric tons of heavy metal of commercial spent nuclear fuel to a proposed privately owned centralized storage facility at Skull Valley in Utah (see Section 8.4 for details).

In light of the uncertainties described above, DOE decided to illustrate the possibilities by focusing the analysis of the No-Action Alternative on the potential impacts of two scenarios:

- Long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years (Scenario 1)

- Long-term storage at the current storage sites with no effective institutional control after about 100 years (Scenario 2)

Although these scenarios would be unlikely, they provide a basis for comparison to the impacts of the Proposed Action and they reflect a range of impacts that could occur.

The following sections describe expected Yucca Mountain site decommissioning and reclamation activities (Section 2.2.1), and further describe the scenarios for continued spent nuclear fuel and high-level radioactive waste management at the commercial and DOE sites (Section 2.2.2). Chapter 7 describes the potential environmental impacts of the No-Action Alternative.

2.2.1 YUCCA MOUNTAIN SITE DECOMMISSIONING AND RECLAMATION

Under the No-Action Alternative, site characterization activities would end at Yucca Mountain and decommissioning and reclamation would begin as soon as practicable and could take several years to complete. Decommissioning and reclamation would include removing or shutting down surface and subsurface facilities, and restoring lands disturbed during site characterization.

Portable and prefabricated buildings would be emptied of their contents, dismantled, and removed from the site. Other facilities could be shut down without being removed from the site. DOE would remove and salvage such equipment as electric generators and tunneling, ventilation, meteorological, and communications equipment. Foundations and similar materials would remain in place.

DOE would remove equipment and materials from the underground drifts and test rooms. Horizontal and vertical drill holes extending from the subsurface would be sealed. Subsurface drifts and rooms would not be backfilled, but would be left with the steel inverts in place. The North and South Portals would be gated to prohibit entry to the subsurface.

Excavated rock piles would be stabilized. Topsoil previously removed from the excavated rock pile area and stored in a stockpile would be returned and the areas would be revegetated. Areas disturbed by surface studies (drilling, trenching, *fault* mapping) or used during site characterization (borrow areas, laydown pads, etc.) would be restored. Fluid impoundments (mud pits, evaporation ponds) would be backfilled or capped as appropriate and reclaimed. Access roads throughout the site (paved or graveled) and parking areas would be left in place and would not be restored.

2.2.2 CONTINUED STORAGE OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT COMMERCIAL AND DOE SITES

Under the No-Action Alternative, spent nuclear fuel and high-level radioactive waste would be managed at the 72 commercial and 5 DOE sites (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, Fort St. Vrain, and the West Valley Demonstration Project) (see Figure 1-1). The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would be treated, packaged, and stored. The amount of spent nuclear fuel and high-level radioactive waste considered in this analysis is the same as that in the Proposed Action—70,000 MTHM, including 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, and 8,315 canisters of solidified high-level radioactive waste (4,667 MTHM). This EIS assumes that the No-Action Alternative would start in 2002.

2.2.2.1 Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection to the environment from spent nuclear fuel and high-level radioactive waste. Because specific designs have not been identified for most locations, DOE selected a representative range of commercial and DOE designs for analysis as described in the following paragraphs.

Spent Nuclear Fuel Storage Facilities

Most commercial nuclear utilities currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor site. Some utilities have built *independent spent fuel storage installations* in which they store spent nuclear fuel dry, above ground, in metal casks or in weld-sealed canisters inside reinforced concrete storage modules. Some utilities are planning to build independent spent fuel storage installations so they can proceed with decommissioning their nuclear plants and terminating their operating licenses (for example, the Rancho Seco and Trojan plants). Because utilities could elect to continue operations until their fuel pools are full and then cease operations, the EIS analysis originally considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However, dry storage is the preferred option for long-term spent nuclear fuel storage at commercial sites for the following reasons (DIRS 101899-NRC 1996, pp. 6-76 and 6-85):

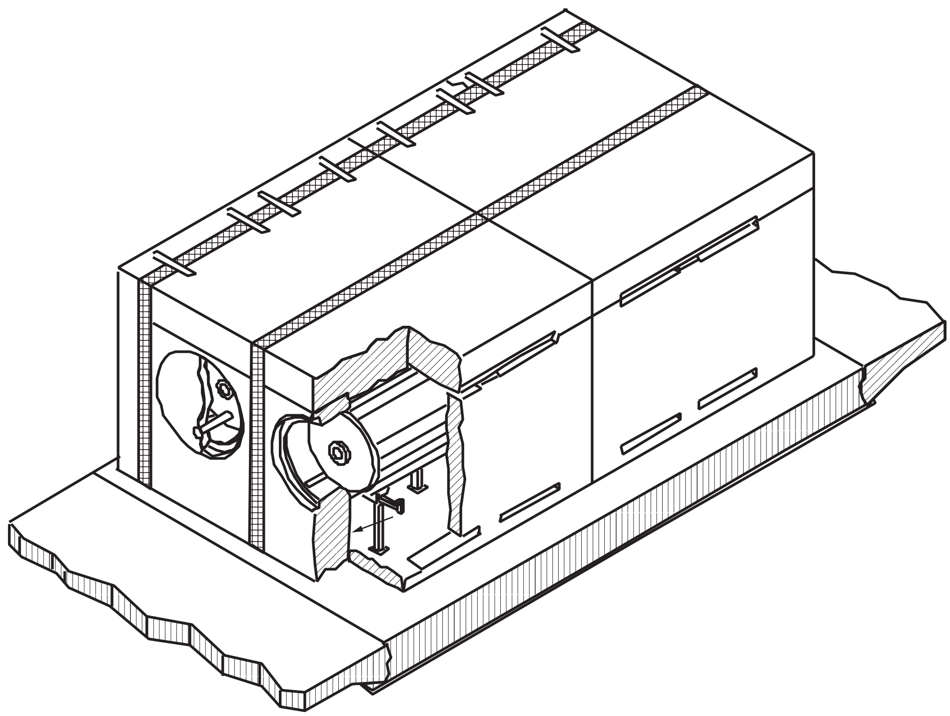
- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, amounts of low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be in dry storage at independent spent fuel storage installations at existing locations. This includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Figure 2-32 shows a photograph of a typical independent spent fuel storage installation at a commercial nuclear site. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluated the impacts of storing all commercial and most DOE spent nuclear fuel in horizontal concrete storage modules (see Figure 2-33) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that both pressurized-water reactor and *boiling-water reactor* spent nuclear fuel would have been loaded into a dry storage canister that would be placed inside the concrete storage module. Figure 2-34 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were properly maintained. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. The concrete storage module would also provide protection from damage from such occurrences as aircraft crashes, earthquakes, and tornadoes.

This analysis assumed that DOE spent nuclear fuel at the Savannah River Site, Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain would be stored dry, above ground in stainless-steel canisters inside concrete casks. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial nuclear sites.

The analysis assumed that DOE spent nuclear fuel at Hanford would be stored dry in below-grade storage facilities. The Hanford N-Reactor fuel would be stored in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. Storage tubes of *carbon steel* would be installed vertically in the vaults. Each storage tube, which would be able to accommodate two spent nuclear fuel canisters, would be closed and sealed with a shield plug. The vaults would be covered by a structural steel shelter.



Source: Modified from DIRS 101910-Poe (1998, p. 1-2).

Figure 2-33. Spent nuclear fuel concrete storage module.

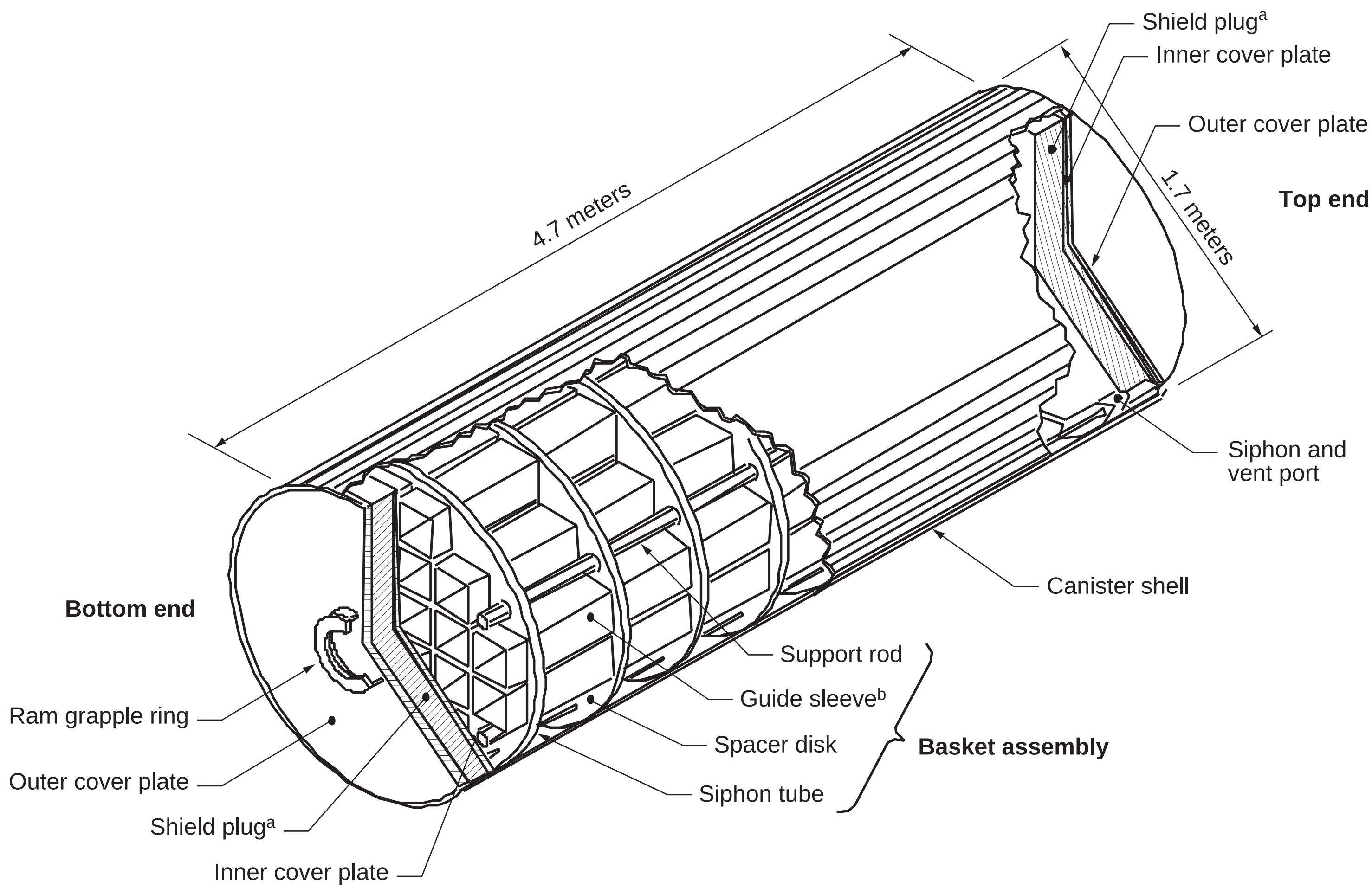
High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that high-level radioactive waste would be stored in a below-grade solidified high-level radioactive waste storage facility (Figure 2-35). At the West Valley Demonstration Project, it was assumed that DOE would use a dry storage system similar to a commercial spent nuclear fuel storage installation for high-level radioactive waste storage.

The high-level radioactive waste storage facility has four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a concrete base mat. Space between the pipes is filled with overlapping horizontally stepped steel plates that direct most of the ventilation air through the storage cavities.

The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment as long as the facilities were maintained. Radiation shielding would be provided by the surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The heat of radioactive decay would be removed from around the canisters by the facility's forced air exhaust system. The exhaust air could be filtered with high-efficiency particulate air filters before it was discharged to the atmosphere through a stack, or natural *convection* cooling could be used with no filter. The oversize diameter of the pipe storage cavities would allow air passage around each cavity.



All materials 304 stainless steel except as noted.

a. Shield plug would be lead.

b. Borated neutron absorber plate for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from DIRS 101910-Poe (1998, p. 1-5).

Figure 2-34. Spent nuclear fuel dry storage canister.

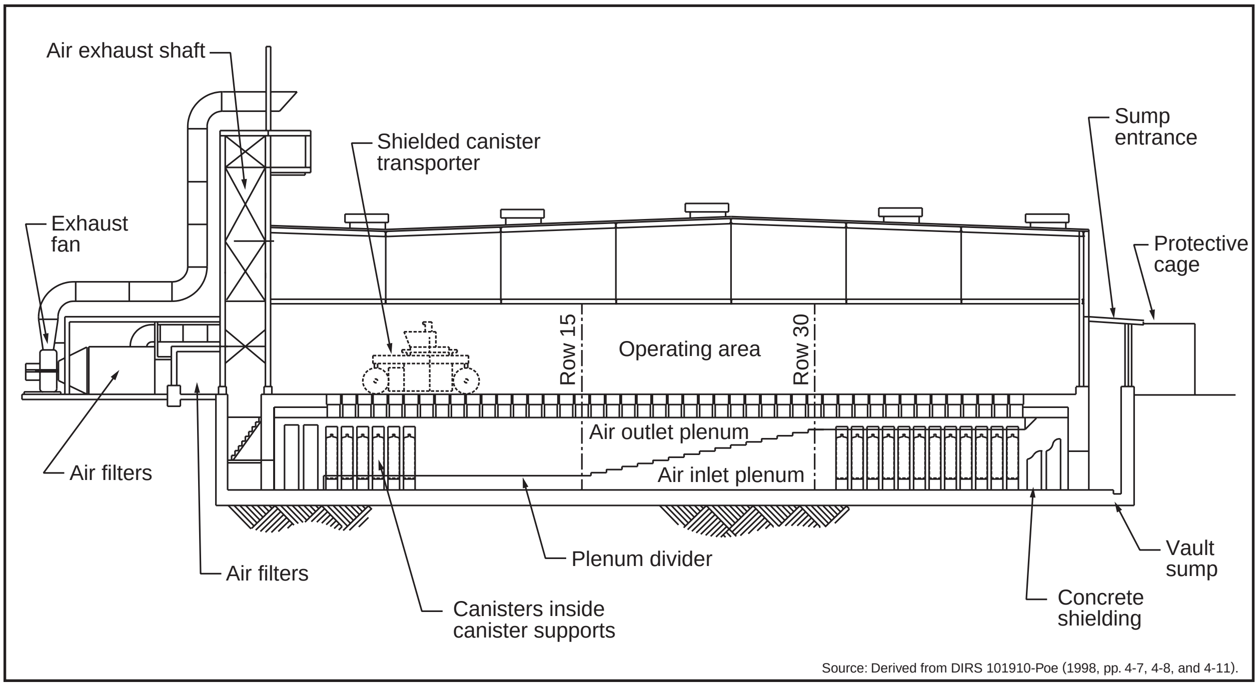


Figure 2-35. Conceptual design for solidified high-level radioactive waste storage facility.

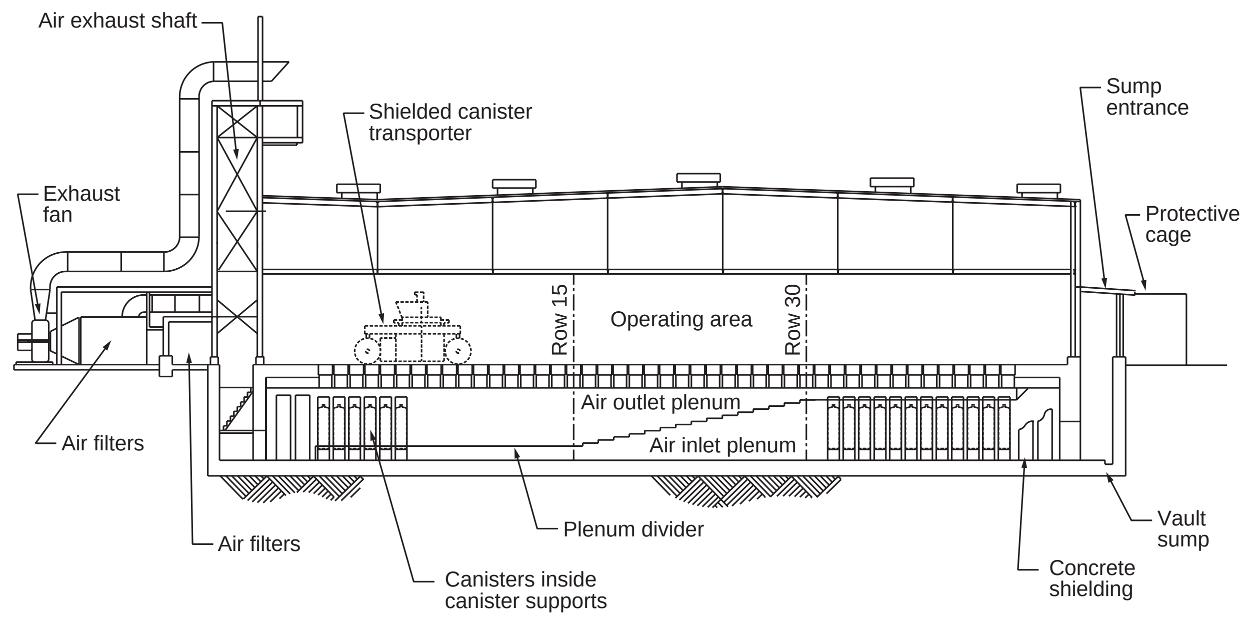
2.2.2.2 No-Action Scenario 1

In No-Action Scenario 1, DOE would continue to manage its spent nuclear fuel and high-level radioactive waste in above- or below-grade dry storage facilities at five sites around the country. Commercial utilities would continue to manage their spent nuclear fuel at 72 sites. The commercial and DOE sites would remain under effective institutional control for at least 10,000 years. Under institutional control, these facilities would be maintained to ensure that workers and the public were protected adequately in accordance with current Federal regulations (10 CFR Parts 20 and 835) and the requirements in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. DOE based the 10,000-year analysis period on the generally applicable Environmental Protection Agency regulation for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), even though the regulation would not apply to disposal at Yucca Mountain.

Under Scenario 1, the storage facilities would be completely replaced every 100 years. They would undergo one major repair during the first 100 years, because this scenario assumes that the design of the first storage facilities at a site would include a facility life of less than 100 years. The 100-year lifespan of future storage facilities is based on analysis of concrete degradation and failure in regions throughout the United States (DIRS 101910-Poe 1998, all). The facility replacement period of 100 years represents the assumed useful lifetime of the structures. Replacement facilities would be built on land adjacent to the existing facilities. After the spent nuclear fuel and high-level radioactive waste had been transferred to the replacement facility, the older facility would be demolished and the land prepared for the next replacement facility, thereby minimizing land-use impacts. The top portion of Figure 2-36 shows the conceptual timeline for activities at the storage facilities for Scenario 1. Only the relative periods shown on this figure, not the exact dates, are important to the analysis.

2.2.2.3 No-Action Scenario 2

In No-Action Scenario 2, spent nuclear fuel and high-level radioactive waste would remain in dry storage at commercial and DOE sites and would be under effective institutional control for approximately



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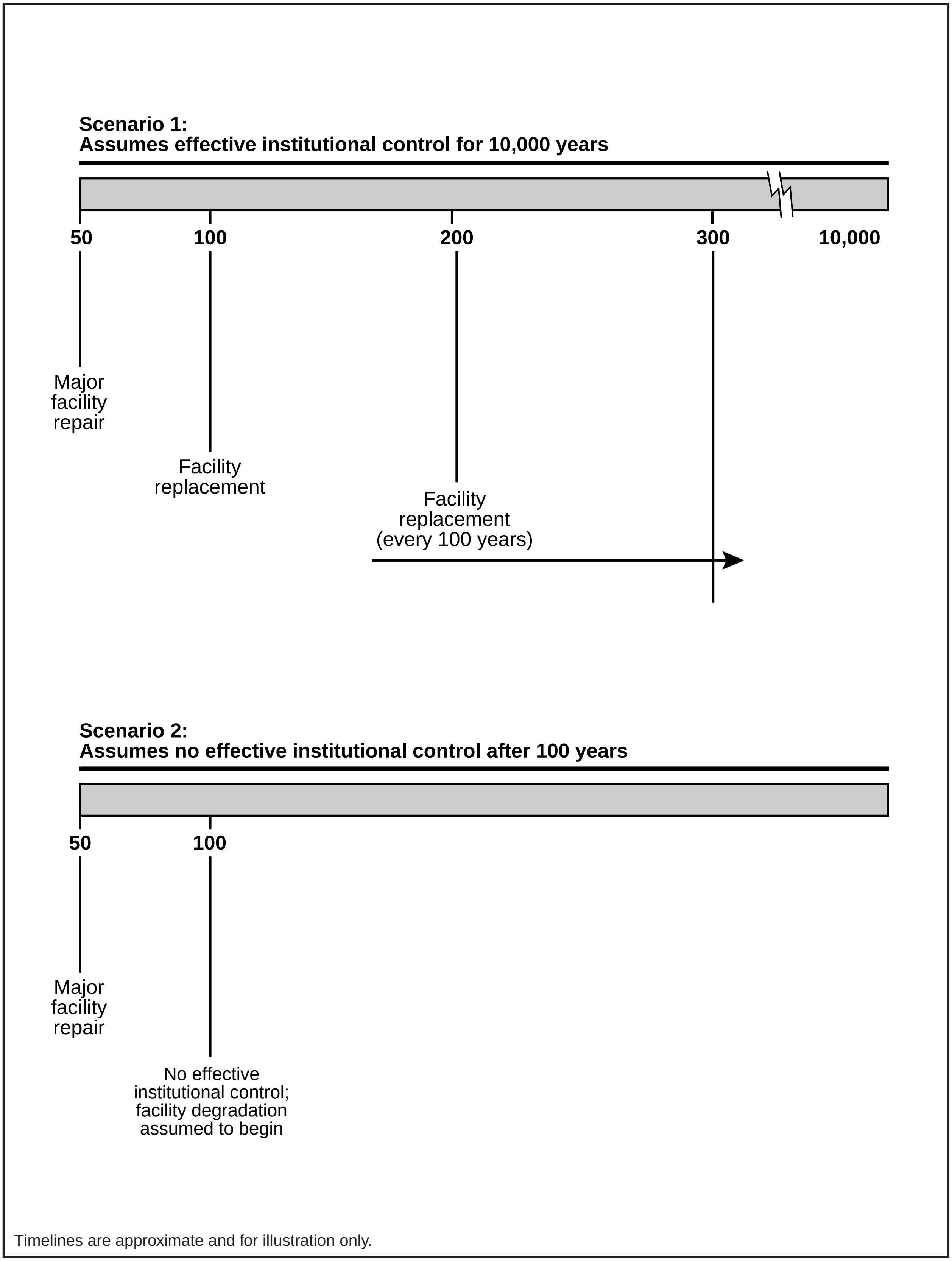

Figure 2-36. Facility timeline assumptions for No-Action Scenarios 1 and 2.

100 years (the same as Scenario 1). Beyond that time, the scenario assumes no effective institutional control. Therefore, after about 100 years and up to 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that the radioactive materials in them could eventually be released to the environment. DOE based the choice of 100 years on a review of generally applicable Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191, Subpart B), Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and a National Research Council report on standards for the proposed Yucca Mountain Repository that generally discounts the consideration of institutional control for longer periods in performance assessments for geologic repositories (DIRS 100018-National Research Council 1995, Chapter 4). The lower portion of Figure 2-36 shows the conceptual timeline for activities at the storage facilities for Scenario 2.

2.2.3 NO-ACTION ALTERNATIVE COSTS

The total estimated cost of the No-Action Alternative includes costs for the decommissioning and reclamation of the Yucca Mountain site, and for the storage of spent nuclear fuel at 72 commercial sites (63,000 MTHM), storage of DOE spent nuclear fuel (2,333 MTHM) at 4 sites (there would be no spent nuclear fuel at the West Valley Demonstration Project), and storage of solidified high-level radioactive waste (8,315 canisters) at 4 sites (there is no high-level radioactive waste at Fort St. Vrain). As listed in Table 2-6, the estimated cost (in 2001 dollars) of both Scenarios 1 and 2 for the first 100 years ranges from $55.7 billion to $61.3 billion, depending on whether the dry storage canisters had to be replaced every 100 years. The estimated costs (in 2001 dollars) for the remaining 9,900 years of Scenario 1 range from $519 million to $572 million per year. There would be no costs for Scenario 2 after the first 100 years because the scenario assumes no effective institutional control.

Table 2-6. No-Action Alternative life-cycle costs (starting in 2002) for 10,000 years (in billions of 2001 dollars).[a,b]

Factor	First 100 years	Remaining 9,900 years (per year)	
	Scenarios 1 and 2[c]	Scenario 1[c,d]	Scenario 2[e]
72 commercial sites (63,000 MTHM)	$43.6 - 49.2	$0.407 - 0.460	$0
DOE spent nuclear fuel storage sites (2,333 MTHM)	8.0	0.075	0
High-level radioactive waste storage sites (8,315 canisters)	4.1	0.038	0
Decommissioning and reclamation of the Yucca Mountain site	(f)	NA[g]	0
Totals	***$55.7 - 61.3***	***$0.519 - 0.572***	***$0***

a. Source: Adapted from DIRS 155929-Jason (1999, all).
b. Adjusted to 2001 dollars, in billions per DIRS 156899-DOE (2001, all).
c. The range of costs for commercial sites is based on the assumption that the spent nuclear fuel would either be placed in dry storage canisters that would not need to be replaced over the 10,000-year period (low cost) or would have to be placed in new dry storage canisters every 100 years (high cost).
d. Stewardship costs are expressed in average annual disbursement costs (year 2001 dollars) only.
e. Costs are not applicable.
f. The costs for decommissioning and reclamation of the Yucca Mountain site would contribute less than 0.1 percent to the total life-cycle cost of continued storage.
g. NA = not applicable.

2.3 Alternatives Considered but Eliminated from Detailed Study

This section addresses alternatives that DOE considered but eliminated from detailed study in this EIS. These include alternatives that the NWPA states this EIS need not consider (Section 2.3.1); design alternatives that DOE considered but eliminated during the evolution of the repository design analyzed in this EIS (Section 2.3.2); and alternative rail corridors and highway routes for heavy-haul trucks and

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Decommissioning and reclamation of the Yucca Mountain site	(f)	NA[g]	0
Totals	***$55.7 - 61.3***	***$0.519 - 0.572***	***$0***

a. Source: Adapted from DIRS 155929-Jason (1999, all).
b. Adjusted to 2001 dollars, in billions per DIRS 156899-DOE (2001, all).
c. The range of costs for commercial sites is based on the assumption that the spent nuclear fuel would either be placed in dry storage canisters that would not need to be replaced over the 10,000-year period (low cost) or would have to be placed in new dry storage canisters every 100 years (high cost).
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2.3.1 ALTERNATIVES ADDRESSED UNDER THE NUCLEAR WASTE POLICY ACT

The NWPA states that, with respect to the requirements imposed by the National Environmental Policy Act, compliance with the procedures and requirements of the NWPA shall be deemed adequate consideration of the need for a repository, the time of the initial availability of a repository, and all alternatives to the isolation of spent nuclear fuel and high-level radioactive waste in a repository [Section 114(f)(2)]. The geologic disposal of radioactive waste has been the focus of scientific research for more than 40 years. Starting in the 1950s, the Atomic Energy Commission and the Energy Research and Development Administration (both predecessor agencies to DOE) investigated different geologic formations as potential hosts for repositories and considered different disposal concepts, including deep-seabed disposal, disposal in the polar ice sheets, and rocketing waste into the sun. After extensive discussion of the options in an EIS (DIRS 104832-DOE 1980, all), DOE decided in 1981 to pursue disposal in an underground mined geologic repository (46 *FR* 26677; May 14, 1981). A panel of the National Academy of Sciences noted in 1990 that there is a worldwide scientific consensus that deep geologic disposal, the approach being followed by the United States, is the best option for disposing of high-level radioactive waste (DIRS 100061-National Research Council 1990, all).

Chapter 1 of this EIS summarizes the process that led to the 1987 amendments to the Nuclear Waste Policy Act of 1982, in which Congress directed DOE to study only Yucca Mountain to determine if it is suitable for a repository. Consistent with this approach, the NWPA states that, for purposes of complying with the requirements of the National Environmental Policy Act, DOE need not consider alternative sites to Yucca Mountain for the repository [Section 114(f)(3)].

Under the Proposed Action, this EIS does not consider alternatives for the emplacement of more than 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement in the first repository of a quantity of spent nuclear fuel containing more than 70,000 MTHM or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent nuclear fuel until a second repository is in operation [Section 114(d)]. However, Chapter 8 of this EIS analyzes the cumulative impacts from the disposal of all projected spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed Yucca Mountain Repository.

2.3.2 REPOSITORY DESIGN ALTERNATIVES ELIMINATED FROM DETAILED STUDY

The preliminary design concept for the proposed Yucca Mountain Repository analyzed in this EIS is the result of a design process that began with early site characterization activities. The design process identified design alternatives (options) that DOE considered. Some of the design options were eliminated from further detailed study during the design evolution. Examples include placement of the emplacement drifts in the *saturated zone* (rather than the *unsaturated zone*); vertical shafts (rather than the gently sloping North and South Ramps); use of drilling and blasting methods for emplacement drift construction (rather than mechanical excavation methods such as tunnel-boring machines); and use of diesel-powered vehicles for waste package emplacement (rather than electrically powered, rail-based vehicles).

DOE recently undertook a comprehensive review and examination of possible design options to provide information for use in support of the suitability recommendation and License Application. Appendix E discusses the design options that DOE considered in this review, and Section 2.1.1.5 discusses their consideration in this EIS.

2.3.3 TRANSPORTATION ALTERNATIVES ELIMINATED FROM DETAILED STUDY

The transportation modes and scenarios analyzed in the EIS are based on DOE's assessment of what would be most feasible and practical for delivering spent nuclear fuel and high-level radioactive waste from generator sites across the continental United States to a repository at Yucca Mountain.

In response to public comments on the Draft EIS, DOE has evaluated the potential for including a large-scale barge scenario and a different mostly rail scenario in which railcars would be used to transport truck casks containing spent nuclear fuel and high-level radioactive waste. The purported advantage of large-scale use of barge transportation was that it would reduce the amount of cross-country overland travel that would be required. However, DOE eliminated the barge modal scenario from further consideration in the EIS because it would be overly complex, requiring greater logistical complexity than either rail or legal-weight truck transportation; a much greater number of large rail casks than rail transport; much greater cost than either rail or legal-weight truck transportation; long transport distances potentially requiring the transit of the Panama Canal outside U.S. territorial waters; transport on intercoastal and coastal waterways of coastal states and on major rivers through and bordering states; extended transportation times; intermodal transfer operations at ports; and land transport from a western port to Yucca Mountain.

DOE also eliminated the truck-cask-on-railcar modal scenarios from future consideration. In this scenario, legal-weight truck casks would be shipped by rail from generator sites to Nevada and then by legal-weight trucks in the State to a Yucca Mountain repository. The purported advantage of this scenario is that DOE could use rail transportation nationally and would not have to construct and operate a branch rail line or upgrade highways, construct an intermodal transfer station, and use heavy-haul trucks in Nevada. DOE determined that while this scenario would be feasible, it would not be practical. The number of shipping casks and railcar shipments would be greater by a factor of 5 than for the mostly rail scenario and the additional cost to the Program would be more than $1 billion. In addition, the truck-casks-on-railcars scenario would lead to the highest estimates of occupational health and public health and safety impacts, most coming from rail-traffic related facilities.

For these reasons, DOE selected the mostly rail and mostly legal-weight truck transportation scenarios as the basis to estimate impacts of transporting spent nuclear fuel to a Yucca Mountain repository. It also evaluated use of barge transportation as a component of the mostly rail scenario for transporting rail casks to nearby railheads from generator sites that could load a rail cask and that are located near navigable waterways but are not served by railroads.

2.3.3.1 Potential Rail Routes Considered but Eliminated from Further Detailed Study

Because rail access is not currently available to the Yucca Mountain site, DOE would have to build a branch rail line from an existing mainline railroad to the repository or transfer rail shipping casks to heavy-haul trucks at an intermodal transfer station to make effective use of rail transportation for shipping spent nuclear fuel and high-level radioactive waste to the repository. Section 2.1.3 describes the 10 implementing rail and intermodal alternatives for Nevada transportation that this EIS evaluates. DOE selected these implementing alternatives based on transportation studies that identified, evaluated, and eliminated other potential Nevada transportation rail and intermodal alternatives (DIRS 104792-YMP 1990, all; DIRS 104795-CRWMS M&O 1995, all; DIRS 101214-CRWMS M&O 1996, all). This section identifies the potential rail and highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study.

In the *Preliminary Rail Access Study* (DIRS 104792-YMP 1990, all), DOE identified 10 potential branch rail line routes to the Yucca Mountain site (Valley, Arden, Jean, Crucero, Ludlow, Mina, Caliente, Carlin, Cherry Creek, and Dike). Figure 2-37 shows these potential rail routes, each named for the area where it would connect to the mainline railroad. Alternatives within each route were developed wherever

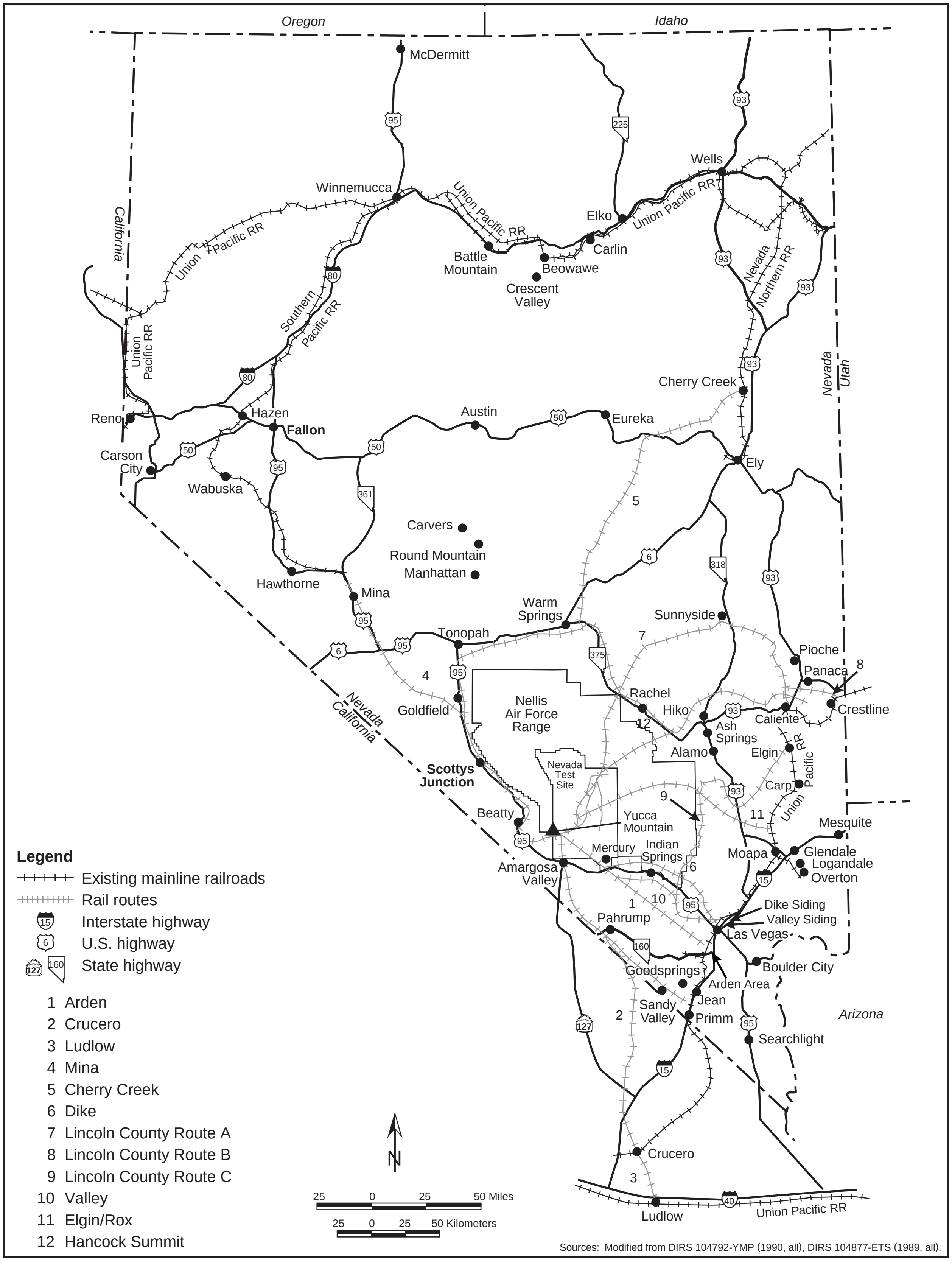

Figure 2-37. Potential rail routes to Yucca Mountain, Nevada, considered but eliminated from further study.

possible. The routes were chosen to maximize the use of Federal lands, provide access to regional rail carriers, avoid obvious land-use conflicts, and meet current railroad engineering practices. After the development of these rail routes, Lincoln County and the City of Caliente identified three additional routes (identified as Lincoln County Routes A, B, and C).

DOE evaluated these 13 potential rail routes in DIRS 104792-YMP (1990, all) and reevaluated them in the *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (DIRS 104795-CRWMS M&O 1995, all). One new route, Valley Modified, was added in the 1995 study based on updated information from the Bureau of Land Management on the status of two Wilderness Study Areas that represent possible land-use conflicts for the Valley route in the original evaluation. Three additional alignments—Caliente-Chalk Mountain, Elgin/Rox, and Hancock Summit—were evaluated in the Nevada Potential Repository Preliminary Assessment of the Caliente-Chalk Mountain Rail Corridor. The evaluations reviewed each potential rail corridor to identify land-use compatibility issues (the presence or absence of land-use conflicts, and the potential for mitigation of a conflict if one exists) and for access to regional rail carriers. The evaluations also compared other factors of the routes, including favorable topography (gently sloping rather than rugged terrain) and avoidance of lands withdrawn from public use by Federal action. Based on these evaluations, DOE eliminated the Valley, Arden, Crucero, Ludlow, Mina, Cherry Creek, Dike, Elgin/Rox, Hancock Summit, and Lincoln County A, B, and C rail routes from further study.

2.3.3.2 Potential Highway Routes for Heavy-Haul Trucks and Associated Intermodal Transfer Station Locations Considered but Eliminated from Further Detailed Study

DOE identified and evaluated potential highway routes for heavy-haul trucks from existing mainline railroads to the Yucca Mountain site (DIRS 104795-CRWMS M&O 1995, all; DIRS 101214-CRWMS M&O 1996, all; DIRS 154448-CRWMS M&O 1998, all). The Department identified highway routes for heavy-haul trucks and associated intermodal transfer station locations to provide reasonable access to existing mainline railroads, to minimize transport length from an existing mainline rail interchange point, and to maximize the use of roads identified by the Nevada Department of Transportation for the highest allowable axle load limits. In addition to the five implementing intermodal alternatives selected for analysis in this EIS (see Section 2.1.3.3), Figure 2-38 shows highway routes for heavy-haul trucks and associated intermodal transfer station locations that DOE considered but eliminated from further detailed study. The eliminated alternatives include four routes named for the location of the intermodal transfer station—Apex, Arden, Baker, and Apex/Dry Lake (Las Vegas Bypass)—and three that are representative of routes from the northern Union Pacific mainline railroad (Northern Routes 1, 2, and 3).

DOE considered the development of new roads for dedicated heavy-haul truck shipments. The analysis assumed those routes would be within the corridors identified for potential rail routes, because the selection criteria for heavy-haul routes and rail routes (land-use compatibility issues, access to regional rail carriers, etc.) would be similar (DIRS 101214-CRWMS M&O 1996, p. 6-3). DOE also considered routes for heavy-haul trucks in the potential rail corridors that could use portions of the existing road system for part of the route length. DOE eliminated the development of a new road for heavy-haul trucks from further detailed evaluation, because the construction of a new branch rail line would be only slightly more expensive and because transportation by rail would not require intermodal transfers and would be more efficient (DIRS 101214-CRWMS M&O 1996, p. 6-7).

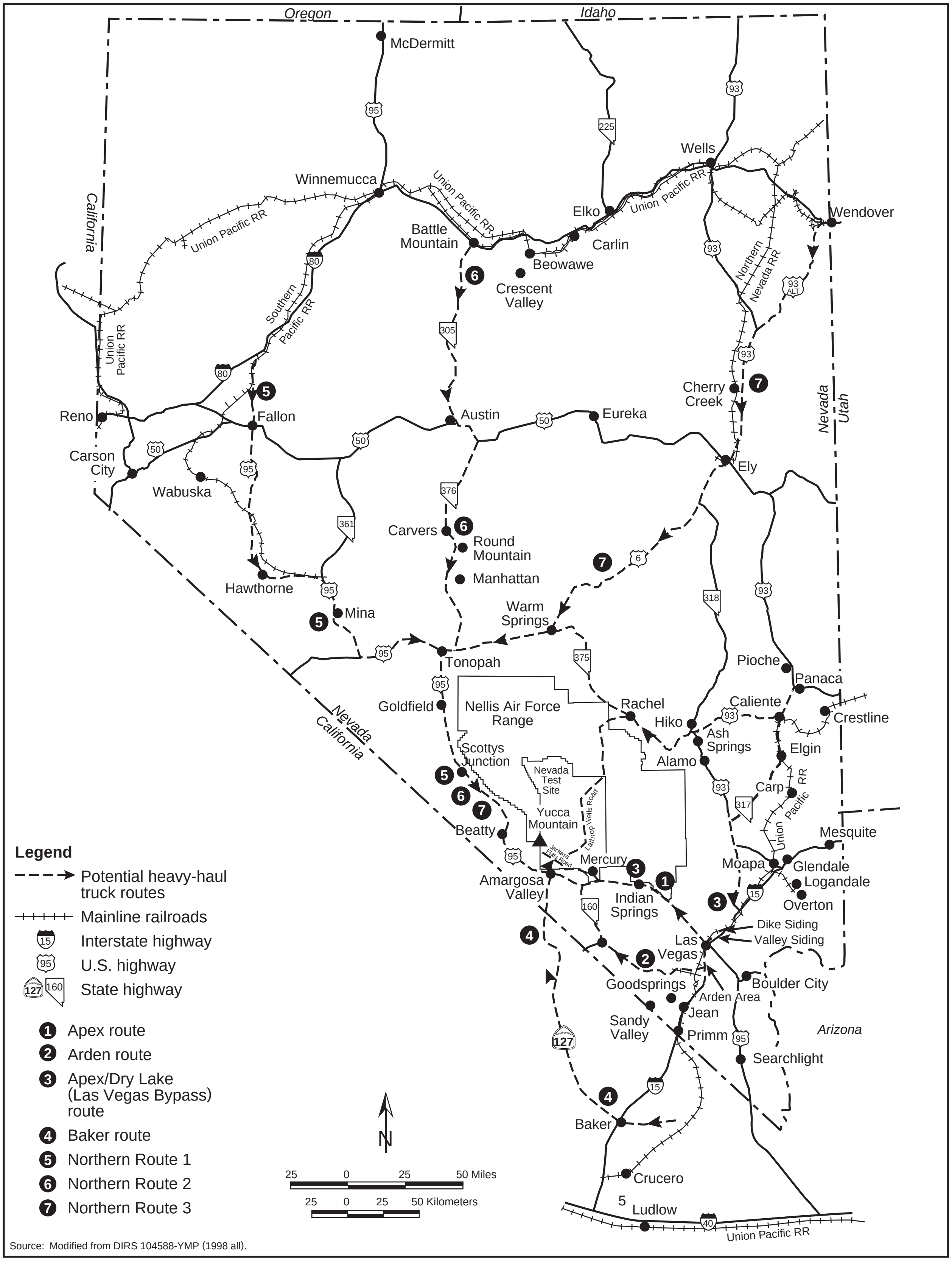

Figure 2-38. Potential highway routes for heavy-haul trucks to Yucca Mountain, Nevada, considered but eliminated from further study.

2.4 Summary of Findings and Comparison of the Proposed Action and the No-Action Alternative

This section summarizes and compares the potential environmental impacts of the Proposed Action and the No-Action Alternative (Section 2.2). Detailed descriptions of the impact analyses are contained in the following chapters:

- Chapter 4 describes the short-term environmental impacts associated with construction, operation and monitoring, and closure of the repository and includes the manufacture of waste disposal containers and shipping casks.
- Chapter 5 describes long-term (postclosure) environmental impacts from the disposal of spent nuclear fuel and high-level radioactive waste in the repository.
- Chapter 6 describes the impacts associated with the transportation of spent nuclear fuel, high-level radioactive waste, other materials, and personnel to and from the repository.
- Chapter 7 describes the short-term and long-term impacts associated with the No-Action Alternative.

This EIS defines *short-term impacts* as those that would occur until and during the closure of the repository and *long-term impacts* as those that would occur after repository closure and for as long as 10,000 years.

This section summarizes the findings of the EIS analyses and contains:

- A general comparison of the impacts of the Proposed Action and No-Action Alternative (Section 2.4.1), with an overall summary of the health impacts
- Short-term impacts of repository construction, operation and monitoring, and closure, including impacts for the operating modes analyzed and short-term impacts of the No-Action Alternative (Section 2.4.2)
- Long-term impacts of the Proposed Action and No-Action Alternative (Section 2.4.3)
- Impacts associated with the transportation scenarios and implementing alternatives (Section 2.4.4)

2.4.1 COMPARISON OF PROPOSED ACTION AND NO-ACTION ALTERNATIVE

In general, the EIS analyses showed that the environmental impacts associated with the Proposed Action would be small to moderate, as described in Chapters 4, 5, 6, and 8. For some of the resource areas specifically analyzed in this study, there would be no impacts. Table 2-7 provides an overview approach to comparing the range of impacts for the Proposed Action (divided into repository, combined national and Nevada transportation, and long-term impacts) and the No-Action Alternative (divided into short-term and the two No-Action long-term scenarios). The sections of the EIS where the reader may find more information about the impacts are noted.

Although generally small, environmental impacts would occur under the Proposed Action. DOE would reduce or eliminate many such impacts with mitigation measures (see Chapter 9) or implementation of standard Best Management Practices (see Chapter 9). Under the No-Action Alternative, the short-term impacts would be the same under Scenario 1 or 2. Under Scenario 1, DOE would continue to manage spent nuclear fuel and high-level radioactive waste facilities at 5 DOE sites, and commercial utilities would continue to manage their spent nuclear fuel at 72 sites on a long-term basis and to isolate the

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 1 of 4).

	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation		(100 years)	Scenario 1	Scenario 2
Land use and ownership	Small; the flexible design range of disturbed land is from 4.3 km^{2}[(b)] to about 6.0 km^2 of the 600 km^2 that comprise the analyzed withdrawal area See Section 4.1.1.2	Small to moderate; 0 to about 20 km^2 of land disturbed for new transportation routes; Air Force identified Nellis Air Force Range conflicts for some routes; some routes pass close to or through Wilderness Study Areas; some corridors could directly impact Native Americans and Indian reservations; and one corridor could conflict with the Ivanpah Airport construction and operation See Section 2.4.4 and Chapter 6	Small; potential for limited access into the area; the only surface features remaining would be markers See Section 5.0	Small; storage would continue at existing sites See Section 7.2.1.1	Small; storage would continue at existing sites See Section 7.2.1.1	Large; potential contamination of 0.04 to 0.4 km^2 surrounding each of the 72 commercial and 5 DOE sites See Section 7.2.2.1
Air quality	Small; releases and exposures well below regulatory limits (less than 6 percent of limits) See Section 4.1.2.5	Small; releases and exposures below regulatory limits; pollutants from vehicle traffic and trains would be small in comparison to other national vehicle and train traffic; Clean Air Act General Conformity Requirements might apply in Clark County Nevada See Section 2.4.4, Tables 2-10 and 2-11, and Chapter 6	Very small, 5.3×10^{-10} latent cancer fatalities peak effect See Section 5.5.2	Small; releases and exposures well below regulatory limits See Section 7.2.1.2	Small; releases and exposures well below regulatory limits See Section 7.2.1.2	Small; degraded facilities would preclude large atmospheric releases See Section 7.2.2.2
Hydrology (groundwater and surface water)	Groundwater–small; water demand (230 to 290 acre-feet[c] per year) well below lowest estimate of the groundwater basin's perennial yield (580 acre-feet) See Section 4.1.3.3	Small; withdrawal of up to 710 acre-feet from multiple wells and hydrographic areas over about 4 years See Section 2.4.4 and Chapter 6	Small amounts of contamination of groundwater in Amargosa Valley during the first 10,000 years. Contamination is several hundred thousand times less than the groundwater protection standard in 40 CFR 197 See Section 5.4.2.1	Small; usage would be small in comparison to other site use See Section 7.2.1.3.2	Small; usage would be small in comparison to other site use See Section 7.2.1.3.2	Large; potential for radiological contamination of groundwater around 72 commercial and 5 DOE sites See Section 7.2.2.3.2
	Surface water–small; new land disturbance of 2.8 to 4.5 square kilometers would result in minor changes to runoff and infiltration rates; floodplain assessment concluded impacts would be small See Section 4.1.3.2	Small; minor changes to runoff and infiltration rates; all rail corridors pass through areas of identified 100-year flood zones, additional floodplain assessments would be performed in the future as necessary See Section 2.4.4 and Chapter 6	Small; minor changes to runoff and infiltration rates See Section 5.0	Small; minor changes to runoff and infiltration rates See Section 7.2.1.3.1	Small; minor changes to runoff and infiltration rates See Section 7.2.1.3.1	Large; potential for radiological releases and contamination of drainage basins downstream of 72 commercial and 5 DOE sites (concentrations potentially exceeding current regulatory limits) See Section 7.2.2.3.1

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 2 of 4).

Resource area	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
	Repository	Transportation			Scenario 1	Scenario 2
Biological resources and soils	Small to moderate; loss of about 4.3 km^2 to 6.0 km^2 of desert soil, habitat, and vegetation; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; wetlands assessment concluded impacts would be small See Section 4.1.4	Small to moderate; loss of 0 to 20 km^2 of desert soil, habitat, and vegetation for heavy-haul routes and rail corridors; adverse impacts to individual threatened desert tortoises (not the species as a whole); reasonable and prudent measures to minimize impacts; impacts to other plants and animals and habitat small; additional wetlands assessments would be performed in the future as necessary prior to any construction See Section 2.4.4 and Chapter 6	Small; slight increase in temperature of surface soil directly over the repository for 10,000 years resulting in a potential temporary shift in plant and animal communities in this small area (about 8 km^2) See Section 5.0	Small; storage would continue at existing sites See Section 7.2.1.4	Small; storage would continue at existing sites See Section 7.2.1.4	Large; potential adverse impacts at each of the 77 sites from subsurface contamination of 0.04 to 0.4 km^2 See Section 7.2.2.4
Cultural resources	Small to moderate; repository development would disturb up to about 4.5 km^2 of previously undisturbed land; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint See Section 4.1.5.2	Small to moderate; loss of 0 to 20 km^2 of land disturbed for new transportation routes; mitigation measures would avoid or minimize damage to and illicit collecting at archaeological sites; programs in place to minimize impacts; opposing Native American viewpoint See Section 2.4.4 and Chapter 6	Small; potential for limited access into the area; opposing Native American viewpoint See Section 5.0	Small; storage would continue at existing sites; limited potential of disturbing sites See Section 7.2.1.5	Small; storage would continue at existing sites; limited potential of disturbing sites See Section 7.2.1.5	Small; no construction or operation activities; no impacts See Section 7.2.2
Socioeconomics	Small; estimated peak total employment of 3,400 occurring in 2006 would result in less than a 1 percent increase in composite regional employment; therefore, impacts would be small. Estimated peak direct employment for the repository during construction would be approximately 1,900 in 2006. See Sections 4.1.6.2.1 and 4.1.6.3	Small; employment increases would range from less than 1 percent to 4.9 percent (use of intermodal transfer station in Lincoln County) of employment in affected counties See Section 2.4.4 and Chapter 6	Small; no workers, no impact See Section 5.0	Small; population and employment changes would be small compared to totals in the regions See Section 7.2.1.6	Small; population and employment changes would be small compared to totals in the regions See Section 7.2.1.6	Small; no workers; no impacts See Section 7.2.2
Occupational and public health and safety						
Public						
Radiological[d]						
MEI (probability of an LCF)	1.6×10^{-5} to 3.1×10^{-5} See Section 4.1.7.5.3	1.4×10^{-4} to 1.2×10^{-3} See Sections 6.1.1 and 6.2.3.2	4×10^{-10} to 4×10^{-9} at the boundary of the controlled area (approximately 18 km south of the repository) See Sections 5.4.2.1 and 5.4.2.2	4.3×10^{-6} See Section 7.2.1.7.3	1.3×10^{-6} See Section 7.2.1.7.3	(e)
Population (LCFs)	0.46 to 2.0 See Section 4.1.7.5.2	0.61 to 2.5 See Section 6.1.1	2×10^{-6} to 3×10^{-4} See Sections 5.4.2.1 and 5.4.2.2	0.41 See Section 7.2.1.7.3	3 See Section 7.2.1.7.3	3,300[f] See Section 7.2.2.5.3

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 3 of 4).

Resource area	Flexible design potential operating modes–range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
	Repository	Transportation			Scenario 1	Scenario 2
Occupational and public health and safety (continued)						
Nonradiological (fatalities due to emissions)	Small; exposures well below regulatory limits See Section 4.1.7	1.6 to 2.8[g] See Sections 6.1.1, 6.1.3, 6.3.2.2.5.6, and 6.3.3.2.1.5	Small; exposures well below regulatory limits or guidelines See Section 5.0	Small; exposures well below regulatory limits or guidelines See Section 7.2.1.7.1	Small; exposures well below regulatory limits or guidelines See Section 7.2.1.7.1	Moderate to large; substantial increases in releases of hazardous substances in the spent nuclear fuel and high-level radioactive waste and exposures to the public See Section 7.2.2
Workers (involved and noninvolved)						
Radiological (LCFs)	4.0 to 6.8 See Section 4.1.7.5.2	3.2 to 11.7 See Section 6.1.1	No workers, no impacts See Section 5.0	16 See Section 7.2.1.7.3	10 See Section 7.2.1.7.3	No workers, no impacts See Section 7.2.2
Nonradiological fatalities (includes commuting traffic fatalities)	2.0 to 3.3 See Section 4.1.7.5.1	12 to 23[h] See Sections 6.1.1, 6.1.3, 6.3.2.2.5.6, and 6.3.3.2.1.5	No workers, no impacts See Section 5.0	9 See Section 7.2.1.7.2 and 7.2.1.14	1,080 See Section 7.2.1.7.2 and 7.2.1.14	No workers, no impacts See Section 7.2.2
Accidents						
Public						
Radiological						
MEI (probability of an LCF)	2.9×10^{-13} to 1.9×10^{-5} See Section 4.1.8.1	0.0015 to 0.015 See Section 6.1.1	Not applicable See Section 5.0	No impacts See Section 7.2.1.8	No impacts See Section 7.2.1.8	Not applicable See Section 7.2.2.7
Population (LCFs)	1.4×10^{-11} to 1.1×10^{-2} See Section 4.1.8.1	0.55 to 5 See Section 6.1.1	Not applicable See Section 5.0	No impacts See Section 7.2.1.8	No impacts See Section 7.2.1.8	3 to 13 See Section 7.2.2.7
Workers	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 4.1.8.1	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 2.4.4 and Chapter 6	No workers, no impacts See Section 5.0	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 7.2.1.8	Large; for some unlikely accident scenarios workers would likely be severely injured or killed See Section 7.2.1.8	Small; no workers; no impacts See Section 7.2.2
Noise/Ground Vibration	Small; impacts to public would be low due to large distances to residences; workers exposed to elevated noise levels – controls and protection used as necessary See Section 4.1.9.2	Small to moderate; transient and not excessive, less noise than 90 dBA[i]; ground vibration infrequent and less than 88 dBV at 25 m See Section 2.4.4 and Chapter 6	Small; no activities, therefore, no noise or ground vibration See Section 5.0	Small; transient and not excessive, less than 90 dBA See Section 7.2.1.9	Small; transient and not excessive, less than 90 dBA See Section 7.2.1.9	Small; no activities, therefore, no noise See Section 7.2.2

Table 2-7. Impacts associated with the Proposed Action and No-Action Alternative[a] (page 4 of 4).

	Flexible design potential operating modes – range of impacts			No-Action Alternative		
	Short-term (through closure)		Long-term (after closure, to 10,000 years)	Short-term (100 years)	Long-term (100 to 10,000 years)	
Resource area	Repository	Transportation			Scenario 1	Scenario 2
Aesthetics	Small; low adverse impacts to aesthetic or visual resources in the area. There may be increase in lighting impacts due to lighting associated with the ventilation system See Section 4.1.10	Small; possible temporary and transient; conflict with visual resource management goals for Wilson Pass Option of the Jean rail corridor; and discernible impacts from the Caliente Intermodal transfer facility near Kershaw-Ryan State Park. See Section 2.4.4 and Section 6.2	Small; only surface features remaining would be markers See Section 5.0	Small; storage would continue at existing sites; expansion as needed See Section 7.2.1.10	Small; storage would continue at existing sites; expansion as needed See Section 7.2.1.10	Small; aesthetic value decreases as facilities degrade See Section 7.2.2
Utilities, energy, materials, and site services	Small; use of materials would be very small in comparison to amounts used in the region; electric power delivery system to the Yucca Mountain site would have to be enhanced See Section 4.1.11.2	Small; use of materials and energy would be small in comparison to amounts used nationally See Section 2.4.4 and Chapter 6	Small; no use of materials or energy See Section 5.0	Small; materials and energy use would be small compared to total site use See Section 7.2.1.11	Small; materials and energy use would be small compared to total site use See Section 7.2.1.11	Small; no use of materials or energy See Section 7.2.2
Management of site-generated waste and hazardous materials	Small; radioactive and hazardous waste generated would be a few percent of existing offsite capacity; other wastes would be managed onsite See Section 4.1.12.2	Small; waste generated would be a fraction of existing offsite capacity See Section 2.4.4 and Chapter 6	Small; no waste generated or hazardous materials used See Section 5.0	Small; waste generated and materials used would be small compared to total site generation and use See Section 7.2.1.12	Small; waste generated and materials used would be small compared to total site generation and use See Section 7.2.1.12	Small; no waste generated or hazardous materials used See Section 7.2.2
Environmental justice	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint See Section 4.1.13	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint See Section 6.1.2.12	Small; no disproportionately high and adverse impacts to minority or low-income populations; opposing Native American viewpoint See Section 5.0	Small; no disproportionately high and adverse impacts to minority or low-income populations See Section 7.2.1.13	Small; no disproportionately high and adverse impacts to minority or low-income populations See Section 7.2.1.13	Large; potential for disproportionately high and adverse impacts to minority or low-income populations See Section 7.2.2.8

a. Ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

b. km^2 = square kilometers; to convert to acres, multiply by 247.1.

c. To convert acre-feet to cubic meters, multiply by 1233.49.

d. LCF = latent cancer fatality; MEI = maximally exposed individual.

e. With no effective institutional controls, the maximally exposed individual could receive a fatal dose of radiation within a few weeks to months. Death would be caused by acute direct radiation exposure.

f. Downstream exposed population of approximately 3.9 billion over 10,000 years.

g. Nonradiological fatalities due to exhaust emissions health effects from spent nuclear fuel and high-level radioactive waste transportation, including loadout; exhaust emissions health effects from commuter and materials transportation for repository construction, operation, and closure; and rail line or heavy-haul truck/intermodal transfer station construction, maintenance, and operation.

h. Nonradiological traffic fatalities from spent nuclear fuel and high-level radioactive waste transportation and commuter traffic fatalities. As many as 10 to 17 of these fatalities could be members of the public.

i. dBA = *A-weighted decibels*, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

material from human access with institutional control. Under Scenario 2, with the assumption of no effective institutional control after 100 years, the spent nuclear fuel and high-level radioactive waste storage facilities would begin to deteriorate and radioactive materials could escape to the environment, contaminating the local atmosphere, soils, surface water, and groundwater, thereby representing a considerable human health risk. As described in Chapter 7, if DOE increased the assumed institutional control period to be consistent with the repository preclosure period (100 to 324 years), the short-term impacts would range up to three times those reported for the No-Action Alternative, depending on the environmental resource area evaluated.

The range of potential health impacts for the Proposed Action, depending on the operating mode, and for the No-Action Alternative are shown in Table 2-8. The transportation-related impacts presented in Table 2-8 represent those associated with the preferred transportation mode (mostly rail). The range of health impacts to workers and the public for repository construction, operation and monitoring, and closure including the full range of possible transportation scenarios and modes would be 24 to 49 fatalities (see Table 2-7), whereas the health impacts for repository construction, operation and monitoring, and closure using the preferred mode of transportation (mostly rail) would be 24 to 38 fatalities (see Table 2-8).

2.4.2 SHORT-TERM IMPACTS OF THE PROPOSED ACTION REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE AND NO-ACTION ALTERNATIVE

DOE analyzed short-term impacts (project start to the end of closure) for the Proposed Action and No-Action Alternative in various resource areas. The information presented in Table 2-7 shows that the short-term environmental impacts for the Proposed Action and the No-Action Alternative would generally be small and do not differentiate dramatically between the two alternatives. The analyses also included cost estimates for the two alternatives. Estimated short-term (to the end of closure) costs (in 2001 dollars) for the Proposed Action would range from $43 to $58 billion, and those for the No-Action Alternative would be as much as $61 billion for the same period (see Sections 2.1.5 and 2.2.3).

To construct the analytical basis for evaluation of repository impacts, DOE used widely accepted analytical tools to estimate potential environmental impacts, coupled with the best available information, and cautious but reasonable assumptions where uncertainties exist. This included applying conservative assumptions to the set of reasonable operating scenarios identified in the Science and Engineering Report (DIRS 153849-DOE 2001, p. 2-24) to ensure that the EIS did not underestimate potential environmental impacts and to accommodate the greatest range of potential future actions.

DOE has established parameters for the range of potential repository operating modes and has identified these parameters and their ranges in Table 2-2. These operating modes provide the basis for evaluation of the environmental impacts described in Chapter 4. Ensuring that the range of potential impacts evaluated fully encompasses the impacts that could occur under any reasonable repository mode of operation requires a basic understanding of how the particular impacts relate to the various parameters, particularly those parameters that could be varied to achieve lower-temperature operation.

As shown in the Draft EIS and the Supplement to the Draft EIS, the short-term impacts (preclosure) would increase with the size of the repository and surface facilities. The smallest repository and surface facilities are associated with the higher-temperature repository operating mode and therefore would result in the lowest short-term environmental impacts. As detailed in Section 2.1.1.2.2, the lower-temperature repository operating mode would be achieved by varying several of the design parameters independently or in combination, for differing effects. Design parameters include waste package loading, repository ventilation duration, and waste package spacing. In the analyses, DOE maximized each of these parameters in turn, and assumed reasonably conservative values for the other dependent parameters to

Table 2-8. Health and safety impact comparison of Proposed Action to No-Action Alternative.[a]

Proposed Action impacts (0 to 10,000 years) Impacts for the preclosure period (up to 341 years)		No-Action impacts (0 to 10,000 years) Impacts from 0 to 100 years	
Radiological		Radiological	
Loadout and transportation of SNF and HLW	4 LCFs	Loadout and transportation of SNF and HLW	0 LCFs
Construction and operations at repository	4 - 8 LCFs	Construction and operations	16 LCFs
Subtotal	8 - 12 LCFs	Subtotal	16 LCFs
Nonradiological		Nonradiological	
Transportation via mostly rail		Transportation (materials and commuting)	7 fatalities
SNF and HLW to Yucca Mountain	3 - 4 fatalities	Construction and operations	2 fatalities
Nevada railroad construction and maintenance	1 - 2 fatalities	Subtotal	9 fatalities
Repository construction, operation and monitoring, and closure	10 - 17 fatalities		
Construction and operations at repository	2 - 3		
Subtotal	16 - 26 fatalities		
Total (preclosure period)	***24 - 38 fatalities or LCFs***	***Total (0 to 100 years)***	***25 fatalities or LCFs***
		Impacts from 100 to 10,000 years	
Impacts from closure to 10,000 years		With institutional control	No institutional control
Radiological	~0 LCF	~13 LCFs	~3,300 LCFs
Transportation	0 fatalities	~760 fatalities	0 fatalities
Construction and operations	0 fatalities	~320 fatalities	0 fatalities
Total (0 to 10,000 years)	***24 - 38 fatalities or LCFs***	***~1,120 fatalities or LCFs***	***~3,325 fatalities or LCFs***

a. Abbreviations: SNF = spent nuclear fuel; HLW = high-level radioactive waste; LCF = latent cancer fatality.

evaluate the full range of potential environmental impacts. As an example, DOE considered a repository with the largest waste package spacing (6.4 meters), with and without the use of surface aging. The result was the largest repository and surface facilities and therefore the highest potential impacts for some environmental resource areas (for example, land disturbance, nonradiological air quality, and water use). Conversely, when DOE assumed the long postemplacement ventilation period (300 years), with and without the surface aging facility, the result was a repository that would be open for a longer period with higher potential for impacts to workers and release of naturally occurring radon from the open repository to the offsite public. DOE evaluated the reasonable combinations of these variable design parameters to establish the range of impacts reported in Chapter 4 and summarized in Table 2-7.

For the No-Action Alternative, short-term actions would be limited to termination of activities and reclamation at the Yucca Mountain site, as well as continued management and storage of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites across the United States. Short-term actions at the repository would include dismantling and removal of surface structures, rehabilitating land disturbed during characterization activities, salvage of usable equipment and materials, sealing of boreholes, and grating of portals. Because the activities (for example, earth moving, facility removal, and site reclamation) would be essentially the reverse of facility construction and reclamation of the site is expected to require 1 year, DOE estimated the resultant impacts as essentially equal to 1 year of repository construction activities (see Chapter 7, Section 7.1, for more details).

For the 77 generator sites, impacts resulting from continued management and storage of spent nuclear fuel and high-level radioactive waste were estimated based on actual operational experience at DOE and commercial storage facilities. In addition, the short-term impacts for the No-Action Scenarios 1 and 2 would be essentially the same because both scenarios assume institutional controls remain in place for the first 100 years. The information in Table 2-7 generally reflects environmental impacts at the generator sites, because the short-term impacts of No-Action at the repository would be much smaller than the collective impacts at the 77 generator sites.

2.4.3 LONG-TERM IMPACTS OF THE PROPOSED ACTION AND THE NO-ACTION ALTERNATIVE

In addition to the short-term impacts described above, DOE assessed the impacts from radiological and nonradiological hazardous materials released over a much longer period (100 years to as long as 10,000 years) after the closure of the repository (for the Proposed Action, DOE also estimated the peak *dose* for the post-10,000 year period). These projections are based essentially on the best available scientific techniques. DOE focused the assessment of long-term impacts on human health, biological resources, surface-water and groundwater resources, and other resource areas for which the analysis determined the information was particularly important.

The EIS also examined possible biological impacts from the long-term production of heat by the radioactive materials disposed of in Yucca Mountain. The analysis determined that there would be small or no long-term impacts to land use, *noise*, socioeconomic resources, cultural resources, surface-water resources, aesthetics, utilities, or site services from the Proposed Action and limited impacts from the No-Action Alternative, depending on the scenario. The analysis led to the following conclusions:

- From 0.04 to 0.4 square kilometer (10 to 100 acres) of land could be contaminated to the extent it would not be usable for long periods near each of the 77 sites for No-Action Scenario 2. There could be accompanying impacts on biological resources, socioeconomic conditions, cultural resources, and aesthetic resources for long periods. Such impacts for the Proposed Action and No-Action Scenario 1 would be very small.

- For No-Action Scenario 2, there could be low levels of contamination in the surface watershed and high concentrations of contaminants in the groundwater downstream of the 77 sites for long periods. There would be no such impacts for No-Action Scenario 1. For the Proposed Action, there could be very low levels of contamination in the groundwater in the *Amargosa Desert* for a long period.

- Projected radiological impacts to the public for the first 10,000 years for the Proposed Action would be low (about 2×10^{-6} to 3×10^{-4} *latent cancer fatality* per year) compared to No-Action Scenario 2 (3,300 latent cancer fatalities over 10,000 years).

- Radionuclides would be released for a long period of time under the Proposed Action and peak doses would occur about 480,000 years after closure of the repository. The peak mean annual effective *dose equivalent* would be 120 to 150 *millirem*.

- Projected long-term (10,000 years) fatalities associated with No-Action Scenario 1 would be about 1,000, primarily to the workforce at the storage sites.

- Risks associated with sabotage and materials diversion in relation to the fissionable material stored at the 77 sites would be much greater than they would be if the fissionable material were in a monitored deep geologic repository.

The projected cost associated with No-Action Scenario 1 would range from $520 million to $570 million a year (2001 dollars) (see Section 2.2.3) for 9,900 years. Projected long-term costs for the Proposed Action would be very low while there would be none for No-Action Scenario 2 due to the lack of institutional control.

2.4.4 IMPACTS OF TRANSPORTATION SCENARIOS

Table 2-7 summarizes the full range of transportation impacts for the construction, operation and maintenance, and closure of the proposed repository, including the mostly rail and mostly legal-weight truck scenarios and the impacts of constructing and using the Nevada implementing alternatives. This range bounds the transportation-related impacts that could occur. Table 2-8 summarizes health and safety impacts for construction, operation and maintenance, and closure of the repository using the preferred transportation mode of mostly rail nationally and in the State of Nevada.

The following sections address health impacts from the movement of spent nuclear fuel and high-level radioactive waste across the Nation (Section 2.4.4.1) and impacts that could occur in the State of Nevada for the legal-weight truck, rail, and heavy-haul truck implementing alternatives (Section 2.4.4.2). The impacts discussed in both sections are included in Tables 2-7 and 2-8, and are described here to show the comparative difference between the 10 transportation implementing alternatives.

2.4.4.1 National Transportation

This section summarizes and compares national transportation-related environmental impacts for the movement of spent nuclear fuel and high-level radioactive waste from the 77 sites to the Yucca Mountain site. Table 2-9 compares the environmental impacts for the two national transportation scenarios, mostly rail and mostly legal-weight truck (see Section 2.1.3.2). Because DOE does not know the actual mix it would use for these potential national transportation modes, the analyses used these two scenarios to bound the impacts from reasonably expected transportation activities that would move spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. In addition to national impacts, Table 2-9 includes estimates of the environmental impacts associated with transportation in Nevada.

Table 2-9. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.[a,b]

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48[c]	48[c]
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	29,000	7,900 - 8,800
	Latent cancer fatality incidence	11.7	3.2 - 3.5[d]
	Industrial safety (fatalities)	0.9	0.29
Public	*Incident-free health impacts, radiological*		
	Average exposed individual (rem)	0.0005	0.0001
	Maximally exposed individual (rem)	2.4[e]	0.29
	Individual latent cancer fatality probability	0.0012	0.00014
	Collective dose (person-rem)	5,000	1,200 - 1,600
	Latent cancer fatality incidence	2.5	0.61 - 0.81
	Incident-free vehicle emissions impacts (fatalities)	0.95	0.55 - 0.77
	Radiological impacts from maximum reasonably foreseeable accident scenario		
	Frequency (per year)	2.3 in 10,000,000	2.8 in 10,000,000
	Maximally exposed individual (rem)	3	29
	Individual latent cancer fatality probability	0.0015	0.015
	Collective dose (person-rem)	1,100	9,900
	Latent cancer fatality incidence	0.55	5
	Accident dose risk (person-rem)	0.46	0.89
	Accident risk (latent cancer fatalities)	0.00023	0.00045
Public and transportation workers	*Fatalities from vehicular accidents*	4.9	2.3 - 3.1

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation, including impacts of loading.
c. Based on 2-rem-per-year dose limit.
d. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.
e. Based on 100-millirem-per-year dose limit.

As discussed in more detail in Chapter 6, shipments of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be a small fraction of the overall railroad and highway shipping activity in the United States. Thus, the incremental impacts from shipments to Yucca Mountain for the resource areas would be small in comparison to background impacts from all shipping activities, with the exception of potential radiological impacts.

The following conclusions can be drawn from the analysis results summarized in Table 2-9:

- Radiological impacts from maximum foreseeable accident scenarios during the transportation of spent nuclear fuel and high-level radioactive waste would be lower for the mostly legal-weight truck scenario. The likelihood that such an accident would occur is extremely small for all scenarios.
- Impacts from the transportation of spent nuclear fuel and high-level radioactive waste from the commercial and DOE sites to the Yucca Mountain site would be low for either national shipping mode.
- Radiological impacts to the public and to workers for national transportation activities would be lower for the mostly rail scenario.

2.4.4.2 Nevada Transportation

For shipments coming into the State of Nevada by rail, there is no branch rail line to connect the national rail routes with the Yucca Mountain site (see Section 2.1.3.3). As a consequence, DOE evaluated the impacts in Nevada of moving spent nuclear fuel and high-level radioactive waste to the site using 10 implementing alternatives. These included five potential corridors for a new branch rail line (see Section 2.1.3.3.2) and five potential combinations of intermodal transfer stations and highway routes for heavy-haul trucks (see Section 2.1.3.3.3).

Tables 2-10 and 2-11 compare the impacts from transportation activities in potential Nevada rail corridors and heavy-haul truck corridors, respectively, and includes the mostly legal-weight truck scenario impacts that would occur in Nevada. In addition, they list the distance of each route. The results include the potential corridor variations in the routes chosen, construction required, and operations. The impacts summarized in Tables 2-10 and 2-11 are based on the impact analyses in Chapter 6, Sections 6.3.1, 6.3.2, and 6.3.3, which delineate the corridor variations. Additional attributes such as cost, institutional acceptability of the route, construction and schedule risk, and operational compatibility could affect a decision on the choice of a transportation mode or route in Nevada.

The following conclusions can be drawn from the information in Tables 2-10 and 2-11:

- Environmental impacts for each of the 10 implementing alternatives would be small.

- With the exception of *collective dose*, the environmental impacts for shipment by legal-weight truck in Nevada would be smaller than those from the 10 implementing alternatives associated with incoming shipments by mostly rail scenario. However, even for shipment by legal-weight truck in Nevada, the projected collective dose impacts would be small (approximately 0.9 latent cancer fatality to both the public and transportation workers) over 24 years.

- With the exception of land use, differences in environmental impacts for the 10 implementing alternatives related to incoming shipments by mostly rail scenario would be small, so environmental impacts do not appear to be a major factor in the selection of transportation mode, route, or corridor in Nevada for incoming rail shipments.

- As much as about 20 square kilometers (4,900 acres) of land would be disturbed for new transportation routes. Three of the rail corridors would encroach on the western and southern boundaries of the Nellis Air Force Range. Of these three, one short segment of the Valley Modified Corridor would not have a variation that could avoid the encroachment. The Caliente-Chalk Mountain Corridor and the Caliente/Chalk Mountain heavy-haul truck route would travel directly through the range. The U.S. Air Force has stated that any route through the Range would have national security implications. Several rail corridors pass through or near Wilderness Study Areas or the proposed Ivanpah Valley Airport. Rail or heavy-haul truck routes could affect the Timbisha Shoshone trust lands, Las Vegas Paiute Reservation, or Moapa Reservation. Some routes could overlap predicted Las Vegas-area growth. Heavy-haul trucks would slow traffic flow.

- Impacts to cultural resources for any of the potential implementing alternative routes or corridors cannot be fully assessed until more detailed archaeological and ethnographic studies are conducted, but they are likely to be similar to one another. Impacts to Native American values could occur from the use of any of the routes including the use by legal-weight trucks of highways in Nevada that would pass through the Moapa and Las Vegas Paiute Indian Reservations.

2.5 Collection of Information and Analyses

DOE conducted a broad range of studies to obtain or evaluate the information needed for the assessment of Yucca Mountain as a monitored geologic repository for spent nuclear fuel and high-level radioactive waste. The Department used the information from these studies in the analyses described in this EIS. Because some of these studies are ongoing, some of the information is incomplete.

impacts in Nevada of moving spent nuclear fuel and high-level radioactive waste to the site using 10 implementing alternatives. These included five potential corridors for a new branch rail line (see Section 2.1.3.3.2) and five potential combinations of intermodal transfer stations and highway routes for heavy-haul trucks (see Section 2.1.3.3.3).

Tables 2-10 and 2-11 compare the impacts from transportation activities in potential Nevada rail corridors and heavy-haul truck corridors, respectively, and includes the mostly legal-weight truck scenario impacts that would occur in Nevada. In addition, they list the distance of each route. The results include the potential corridor variations in the routes chosen, construction required, and operations. The impacts summarized in Tables 2-10 and 2-11 are based on the impact analyses in Chapter 6, Sections 6.3.1, 6.3.2, and 6.3.3, which delineate the corridor variations. Additional attributes such as cost, institutional acceptability of the route, construction and schedule risk, and operational compatibility could affect a decision on the choice of a transportation mode or route in Nevada.

The following conclusions can be drawn from the information in Tables 2-10 and 2-11:

- Environmental impacts for each of the 10 implementing alternatives would be small.

- With the exception of *collective dose*, the environmental impacts for shipment by legal-weight truck in Nevada would be smaller than those from the 10 implementing alternatives associated with incoming shipments by mostly rail scenario. However, even for shipment by legal-weight truck in Nevada, the projected collective dose impacts would be small (approximately 0.9 latent cancer fatality to both the public and transportation workers) over 24 years.

- With the exception of land use, differences in environmental impacts for the 10 implementing alternatives related to incoming shipments by mostly rail scenario would be small, so environmental impacts do not appear to be a major factor in the selection of transportation mode, route, or corridor in Nevada for incoming rail shipments.

- As much as about 20 square kilometers (4,900 acres) of land would be disturbed for new transportation routes. Three of the rail corridors would encroach on the western and southern boundaries of the Nellis Air Force Range. Of these three, one short segment of the Valley Modified Corridor would not have a variation that could avoid the encroachment. The Caliente-Chalk Mountain Corridor and the Caliente/Chalk Mountain heavy-haul truck route would travel directly through the range. The U.S. Air Force has stated that any route through the Range would have national security implications. Several rail corridors pass through or near Wilderness Study Areas or the proposed Ivanpah Valley Airport. Rail or heavy-haul truck routes could affect the Timbisha Shoshone trust lands, Las Vegas Paiute Reservation, or Moapa Reservation. Some routes could overlap predicted Las Vegas-area growth. Heavy-haul trucks would slow traffic flow.

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Table 2-10. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Mostly rail with branch rail					Mostly legal-weight truck
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	
Corridor length (kilometers)	512 - 553	514 - 544	344 - 382	181 - 204	159 - 163	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	18 - 20	19 - 20	13 - 14	9.2 - 10	5 - 5.2	0
Private land (square kilometers)	0.9 - 2.5	7.3 - 15	0.8 - 1.1	0.1 - 3.5	0 - 0.18	0
Nellis Air Force Range land (square kilometers)	0 - 11	0 - 11	22	0	3.6 - 7.5	0
Tribal	0 - 1.6	0 - 1.6	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - branch rail line not a significant source of pollution	Clark County is in nonattainment of air quality standards for PM_{10} - branch rail line construction could be a significant source of pollution[b]	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Surface water resources along route	5	6	3	0	0	NA[d]
Flood zones	9	11	At least 3	7	2	NA
Groundwater						
Water use (acre-feet)[c]	710	660	480	410	320	0
Water use (number of wells)	64	67	43	23	20	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological or historical resources. Route passes close to the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Moderate	Low	Moderate	Moderate	Moderate	Low
Utilities and resources						
Diesel (million liters)[e]	45	41	36	30	14	Very low
Gasoline (thousand liters)	940	840	680	570	280	
Steel (thousand metric tons)[f]	78	75	52	29	23	0
Concrete (thousand metric tons)[g]	460	420	310	170	130	0

Table 2-10. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Mostly rail with branch rail: Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	Mostly legal-weight truck
Aesthetics	Very low	Very low	Very low	Potential small area of conflict	Very low	None
Socioeconomics						
New jobs (percent of workforce in affected counties	840 (< 1% - 3.2%)	780 (< 1%)	650 (<1% - 2.3%)	530 (< 1%)	250 (< 1%)	Very low
Peak real disposable income (million dollars)	24	21	19	15	7	Very low
Peak incremental Gross Regional Product (million dollars)	40	36	31	26	13	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	220	200	180	150	110	NA
Lost workday cases	110	100	90	80	60	NA
Fatalities	0.43	0.41	0.38	0.3	0.25	NA
Collective dose (person-rem [LCFs])						
Workers	850 [0.34]	980 [0.39]	740 [0.3]	760 [0.3]	710 [0.28]	1,900 [0.75]
Public	19 [0.009]	38 [0.019]	50 [0.025]	130 [0.06]	23 [0.012]	340 [0.17]
Fatalities from vehicle emissions	0.25	0.25	0.2	0.23	0.13	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	1.9	1.8	1.5	1.2	0.9	NA
SNF[h] and HLW[i] shipping	0.07	0.09	0.05	0.06	0.05	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.002	0.003	0.002	0.007	0.002	0.053
Latent cancer fatalities	0.0000009	0.0000013	0.0000009	0.0000036	0.000001	0.000026
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	0.3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. Convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. To convert liters to gallons, multiply by 0.26418.
d. To convert metric tons to tons, multiply by 1.1023.
e. To convert cubic feet to cubic meters, multiply by 0.028317.
f. NA = not applicable.
g. SNF = spent nuclear fuel.
h. HLW = high-level radioactive waste.
i. Conformity analysis may be required (see Chapter 3, Sections 3.1.2.1 and 3.2.2.1.2).

Table 2-11. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 1 of 3).

	Mostly rail with heavy-haul truck					
Impact	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Corridor length (kilometers)	530	280	380	190	180	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	3.4	1.3	2.1	0.63	0.63	0
Private land (square kilometers)	0	0	0	0	0	0
Nellis Air Force Range land (square kilometers)	0	0	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - not a significant source of pollution	Areas in attainment of air quality standards - not a significant source of pollution	Clark County is in nonattainment of air quality standards - heavy-haul route construction could be a significant source of pollution[b]	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)[c]	100	60	44	8	8	0
Water use (number of wells)	16	5	7	Truck water	Truck water	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources; route near Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; route passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; IMT[d] and route near the Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Low	Low	Low	Low	Low	Low
Utilities and resources						
Diesel (million liters)[e]	13	4.7	5.5	1.7	1.6	Very low
Steel (metric tons)[f]	49	14	21	2.3	2.3	0
Concrete (thousand metric tons)[g]	1.8	0.5	0.8	0.1	0.1	0
Aesthetics	Some potential near Caliente	Some potential near Caliente	Some potential near Caliente	Very low	Very low	None

Table 2-11. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 2 of 3).

	Mostly rail with heavy-haul truck					
Impact	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Socioeconomics						
New jobs (percent of workforce in affected counties)	860 (< 1% - 3.3%)	750 (< 1% - 4.9%)	590 - 1,980 (< 1% - 3.3%)	630 - 3,050 (< 1%)	490 - 1,880 (< 1%)	Very low
Peak real disposable personal income (million dollars)	27	22	19 - 65	21 - 97	16 - 62	Very low
Peak incremental Gross Regional Product (million dollars)	45	40	33 - 104	36 - 153	29 - 100	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	310	270	260	150	150	NA[h]
Lost workday cases	160	140	140	80	80	NA
Fatalities	0.72	0.68	0.63	0.37	0.37	NA
Collective dose (person-rem [LCFs])						
Workers	1,600 [0.65]	1,200 [0.50]	1,400 [0.56]	1,200 [0.48]	1,100 [0.46]	1,900 [0.75]
Public	76 [0.038]	61 [0.030]	220 [0.11]	300 [0.15]	160 [0.08]	340 [0.17]
Fatalities from vehicle emissions	0.47	0.32	0.46	0.42	0.29	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	3.5	2.4	3.0	1.7	1.7	NA
SNF[i] and HLW[j] shipping	0.6	0.33	0.43	0.25	0.23	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.01	0.002	0.056	0.12	0.056	0.053
Latent cancer fatalities	0.0000051	0.000001	0.000028	0.00006	0.000028	0.000026

Table 2-11. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 3 of 3).

Impact	Mostly rail with heavy-haul truck: Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. To convert square kilometers to acres, multiply by 247.1.
b. To convert acre-feet to gallons, multiply by 325,850.1.
c. IMT = intermodal transfer.
d. To convert liters to gallons, multiply by 0.26418.
e. To convert metric tons to tons, multiply by 1.1023.
f. To convert cubic feet to cubic meters, multiply by 0.028317.
g. NA = not applicable.
h. SNF = spent nuclear fuel.
i. HLW = high-level radioactive waste.
j. Conformity analysis may be required (see Chapter 3, Sections 3.1.2.1 and 3.2.2.1.2).

The complexity and variability of the natural system at Yucca Mountain, the long periods evaluated, and factors such as the use of incomplete information or the unavailability of information have resulted in a certain degree of uncertainty associated with the analyses and findings in this EIS. DOE believes that it is important that the EIS identify the use of incomplete and unavailable information and uncertainty to enable an understanding of its findings. It is also important to understand that research can produce results or conclusions that might disagree with other research. The interpretation of results and conclusions has resulted in the development of views that differ from those that DOE presents in this EIS. DOE has received input from a number of organizations interested in the Proposed Action or No-Action Alternative or from potential recipients of impacts from those actions. These organizations include among others the State of Nevada, local governments, and Native American tribes. Their input includes documents that present research or information that in some cases disagrees with the views that DOE presents in this EIS. The Department reviewed these documents and evaluated their findings for inclusion as part of the EIS analyses. If the information represents a substantive view, DOE has made every effort to incorporate that view in the EIS and to identify its source.

2.5.1 INCOMPLETE OR UNAVAILABLE INFORMATION

Some of the analyses in this EIS had to use incomplete information. To ensure an understanding of the status of its information, DOE has identified the use of incomplete information or the unavailability of information in the EIS in accordance with the Council on Environmental Quality regulations pertaining to incomplete and unavailable information (40 CFR 1502.22). Such cases describe the basis for the analyses, including assumptions, the use of preliminary information, or conclusions from draft or incomplete studies. DOE continues to study issues relevant to understanding what could happen in the future at Yucca Mountain and the potential impacts associated with its use as a repository. As a result, this Final EIS includes information that was not available for the Draft EIS. DOE believes that sufficient information is currently available to assess the range of impacts that could result from either the Proposed Action or the No-Action Alternative.

2.5.2 UNCERTAINTY

The results and conclusions of analyses often have some associated uncertainty. The uncertainty could be the result of the assumptions used, the complexity and variability of the process being analyzed, the use of incomplete information, or the unavailability of information. To enable an understanding of the status of its findings, this EIS contains descriptions of the uncertainties, if any, associated with the results and conclusions presented. Chapter 5, Section 5.2.4 provides further description of uncertainties associated with estimating long-term impacts.

2.5.3 OPPOSING VIEWS

In this EIS, opposing views are defined as differing views or opinions currently held by organizations or individuals outside DOE. These views are considered to be opposing if they include or rely on data or methods that DOE is not currently using in its own impact analysis. In addition, these views are reasonably based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS.

DOE has attempted to identify and address the range of opposing views in this EIS. The Department identified potential opposing views by reviewing public comments received during the EIS comment period, as well as, published or other information in the public domain. Sources of information included reports from universities, other Federal agencies, the State of Nevada, counties, municipalities, other local governments, and Native American tribes. DOE reviewed the potential opposing views to determine if they:

- Address issues analyzed in the EIS
- Differ from the DOE position
- Are based on scientific, regulatory, or other information supported by credible data or methods that relate to the impacts analyzed in the EIS
- Have significant basic differences in the data or methods used in the analysis or to the impacts described in the EIS

DOE has included potential opposing views that met the above criteria in the EIS where it discusses the particular subject. For example, opposing views on the groundwater system are discussed in the sections on groundwater.

2.5.4 PERCEIVED RISK AND STIGMA

During the scoping process for the Draft EIS, commenters requested DOE to evaluate the potential impacts that could arise from risk perception and stigma associated with the construction and operation of a repository at Yucca Mountain and from the transportation of spent nuclear fuel and high-level radioactive waste. Commenters stated that negative perceptions of the repository and associated transportation would result in substantial adverse socioeconomic impacts, particularly in Nevada.

> **PERCEIVED RISK AND STIGMA**
>
> DOE uses the term risk perception to mean how an individual perceives the amount of risk from a certain activity. Studies show that perceived risk varies with certain factors, such as whether the exposure to the activity is voluntary, the individual's degree of control over the activity, the severity of the exposure, and the timing of the consequences of the exposure.
>
> DOE uses stigma to mean an undesirable attribute that blemishes or taints an area or locale.

In considering the request to evaluate the impacts of risk perception and stigma, DOE recognized that nuclear facilities can be perceived to be either positive or negative, depending on the underlying value systems of the individual forming the perception. Thus, perception-based impacts would not necessarily depend on the actual physical impacts or risk of repository operations, including transportation. A further complication is that people do not consistently act in accordance with negative perceptions, and thus the connection between public perception of risk and future behavior would be uncertain or speculative at best. For these reasons, DOE concluded that including analyses of perception-based and stigma-related impacts in the Draft EIS would not provide meaningful information.

Comments on the Draft EIS and Supplement to the Draft EIS once again raised the issue of risk perception and stigma. In response, DOE examined relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently since scoping to allow DOE to quantify the impact of public risk perception on economic development or property values in affected communities. Of particular interest were those scientific and social studies carried out in the past few years that directly relate to either Yucca Mountain or to DOE actions, such as the transportation of foreign research reactor fuel (see Appendix N). DOE also reexamined the conclusions of previous literature reviews, such as that conducted in 1995 by the Nuclear Waste Technical Review Board.

After completing its review, DOE concluded that, although public perception regarding the proposed geologic repository and transportation of spent nuclear fuel and high-level radioactive waste could be measured, there is no valid method to translate these perceptions into quantifiable economic impacts. Researchers in the social sciences have not found a way to reliably forecast linkages between perceptions or attitudes reported in surveys and actual future behavior. Based on the current limitations in forecasting future behavior attributable to risk perception or stigma, there is a consensus among social scientists that a quantitative assessment of economic impacts from risk perception and stigma is impossible at this time. At best, only a *qualitative* assessment is possible about what broad outcomes seem most likely.

Qualitatively, in the absence of a large accident or a continuing series of smaller accidents, there is little reason to expect that negative perceptions about repository operations are likely to engender adverse effects (see Appendix N). Likewise, absent accidents, there is no reason to expect that risk perceptions would impact property values in areas beyond the transportation corridors. Some studies (DIRS 156055-UER 2001, all; DIRS 156003-Gawande and Jenkins-Smith 2001, all) report that, at least temporarily, a small relative decline in residential property values might result from the designation of transportation corridors in urban areas, even in the absence of accidents. Other transportation experiences (for example, transportation of *transuranic waste* to the Waste Isolation Pilot Plant) suggest that impacts on property values might be negligible or nonexistent.

Based on the general research to date on perceptions and future behavior, and research related specifically to a Yucca Mountain repository, other nuclear facilities, and transportation of spent nuclear fuel and high-level radioactive waste, DOE has concluded that:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be quantified with any degree of certainty.
- Much of the uncertainty is irreducible.
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which may not occur. Consequently, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this EIS.

The studies and literature reviewed are referenced in a report included in Appendix N, *Are Fear and Stigmatization Likely, and How Do They Matter? Lessons from Research on the Likelihood of Adverse Socioeconomic Impacts from Public Perceptions of the Yucca Mountain Repository* by Dr. Robert O'Connor.

2.6 Preferred Alternative

DOE's preferred alternative is to proceed with the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The analyses in this EIS did not identify any potential environmental impacts that would be the basis for not proceeding with the Proposed Action. Further, DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada.

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DOE recognizes that implementation of the Proposed Action would require the completion of a number of actions. As part of this process, the Secretary of Energy is to:

- Undertake (and complete) site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.
- Determine whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the NWPA requires that a comprehensive statement of the basis for the recommendation, including this Final EIS, accompany the recommendation. DOE has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS and other information described below, in making a determination on whether to recommend the site to the President. The NWPA also requires DOE to hold hearings to provide the public in the vicinity of Yucca Mountain with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, the Secretary made a determination to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after the notification, the Secretary would submit the recommendation to the President to approve the site for development of a repository.

If, after a recommendation by the Secretary, the President considered the site qualified for application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may object to the site by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submitted such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature did submit such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

In determining whether to recommend the Yucca Mountain site to the President, the Secretary would consider not only the potential environmental impacts identified in this EIS, but other information designated in Section 114 of the NWPA. These include, for example, a description of the proposed repository, preliminary engineering specifications for the facility, a description of the proposed waste form, an explanation of the relationship between the proposed waste form or packaging and geologic medium of the site, a discussion of the site characterization data that relates to the safety of the site, preliminary comments of the Nuclear Regulatory Commission concerning the sufficiency of information for inclusion in any Departmental license application, and the views and comments of the Governor and Legislature of any State or the governing body of any affected Native American tribe.

As part of the Proposed Action, which DOE has identified as its preferred alternative, the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the comparative impacts of truck and rail transportation nationally and in Nevada, as well as impacts in Nevada of alternative intermodal (rail-to-truck) transfer stations associated routes for heavy-haul trucks and alternative corridors for a branch rail line. The analysis did not identify any potential environmental impacts that would be a basis for not transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site.

DOE believes that the EIS provides the environmental impact information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside

Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as it preferred mode of transportation, both nationally and in Nevada. The environmental impacts for mostly rail are expected to be less overall than the impacts for mostly truck. For the mostly rail scenario, 9,600 rail and 1,100 truck shipments are expected for shipping 70,000 MTHM and, for the mostly truck scenario, 53,000 truck and 300 rail shipments are expected. The reduced number of shipments to move 70,000 MTHM and corresponding expected reduction in environmental impacts are the basis for preferring the mostly rail scenario.

NONPREFERRED ALTERNATIVES

DOE has identified the Caliente-Chalk Mountain rail corridor and heavy-haul truck route as "nonpreferred alternatives." The U.S. Air Force has stated that it knows of no route across the Nellis Air Force Range (now known as the Nevada Test and Training Range) that would avoid militarily sensitive areas and not affect the heavy volume of testing and training that occurs daily. Therefore, the Air Force believes that such a route would be inconsistent with the national security uses of the Range.

At this time, DOE has not identified a preference for a specific rail corridor in Nevada. If the Yucca Mountain site was approved, DOE would identify such a preference in consultation with affected stakeholders, particularly the State of Nevada. In that case, DOE would announce its preferred corridor in Nevada in a *Federal Register* notice. Following the *Federal Register* notice, DOE would publish its decision to select a corridor in a Record of Decision no sooner than 30 days after the announcement of a preference. However, follow-on implementing decisions, such as selection of a specific rail alignment in a corridor, would require additional field surveys, state and local government consultations, Native American tribal consultations, environmental and engineering analyses, and National Environmental Policy Act reviews.

REFERENCES

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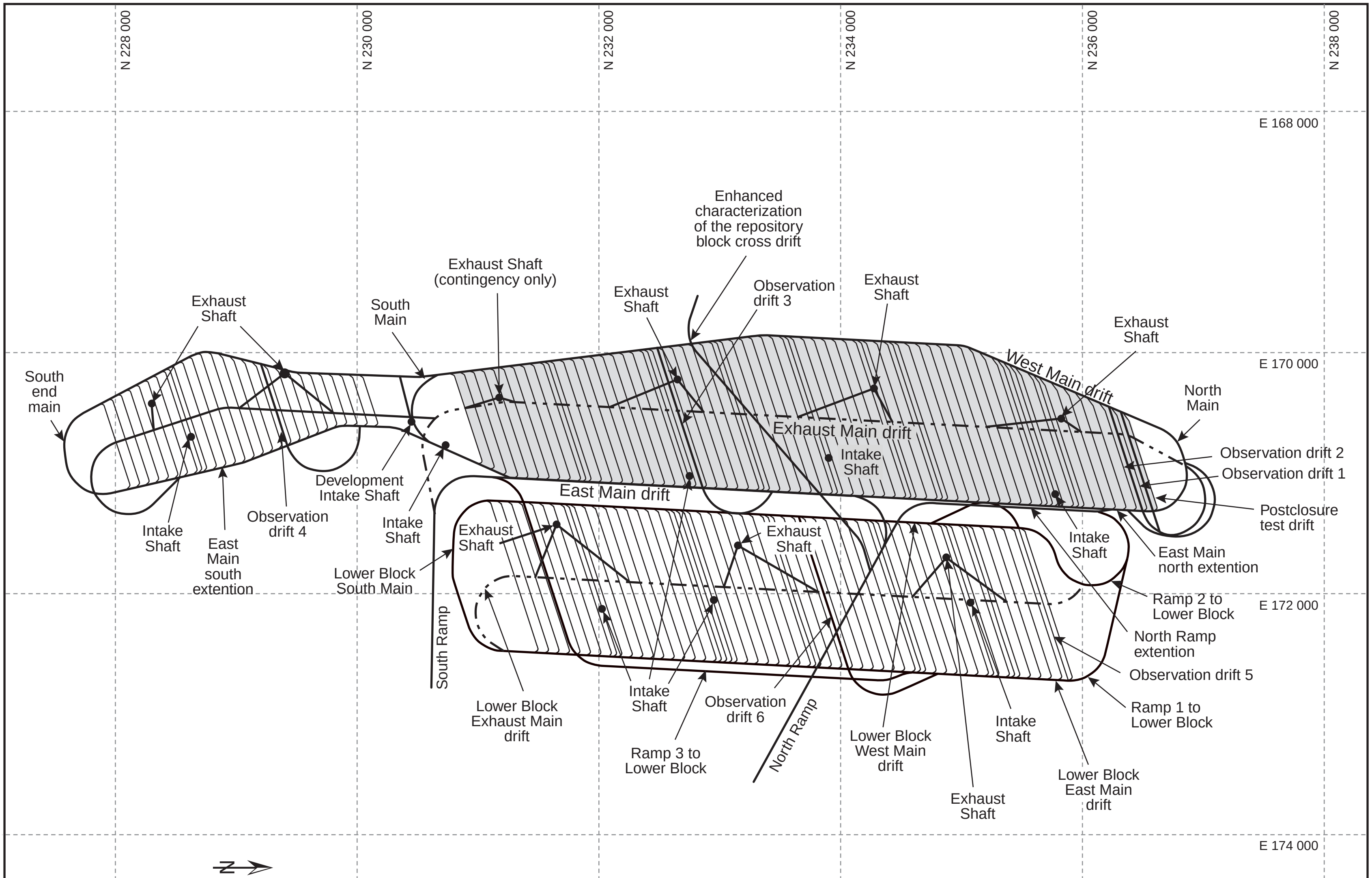
154554	BSC 2001	BSC (Bechtel SAIC Company) 2001. *Lower-Temperature Subsurface Layout and Ventilation Concepts*. ANL-WER-MD-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010718.0225.
104795	CRWMS M&O 1995	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1995. *Nevada Potential Repository Preliminary Transportation Strategy Study 1*. B00000000-01717-4600-00023 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960729.0195. In the Draft EIS, this reference was cited as TRW 1995a in Chapter 12.



Legend

- Ventilation drift
- Possible minimum emplacement drift area for higher-temperature operating mode

Note: The grid system is the Nevada State Plane Coordinate System converted to metric units. E = Easting; N = Northing.

Source: Modified from DIRS 104523-CRWMS M&O (1999, Figure 3.3-1, Figure 3.3-2, Figure 3.3-3); DIRS 153849-DOE (2001, Figure 2-10).

Figure 2-13. Flexible design operating mode repository layout showing possible maximum emplacement drift area.

Figure 2-14. Tunnel boring machine.

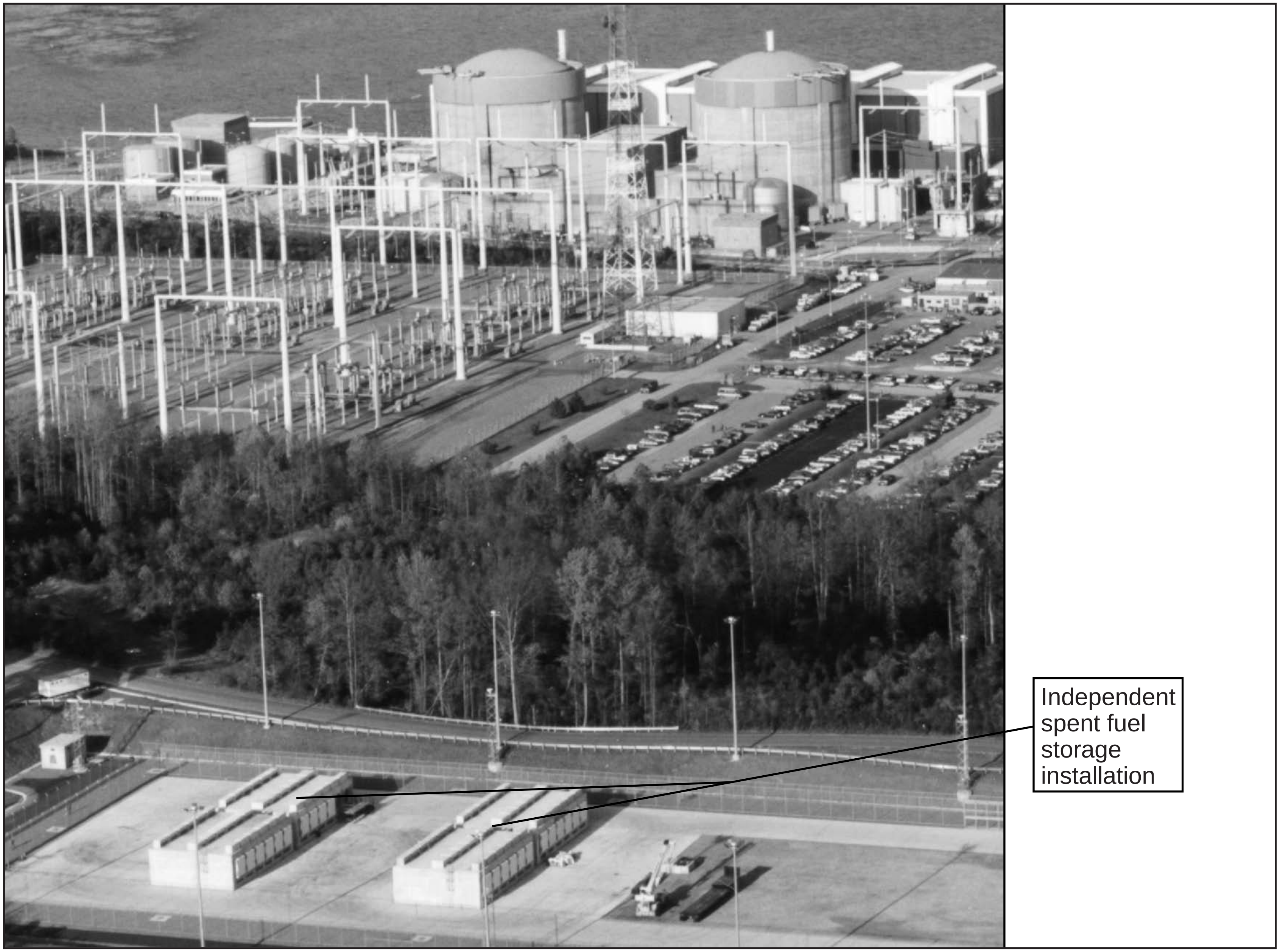
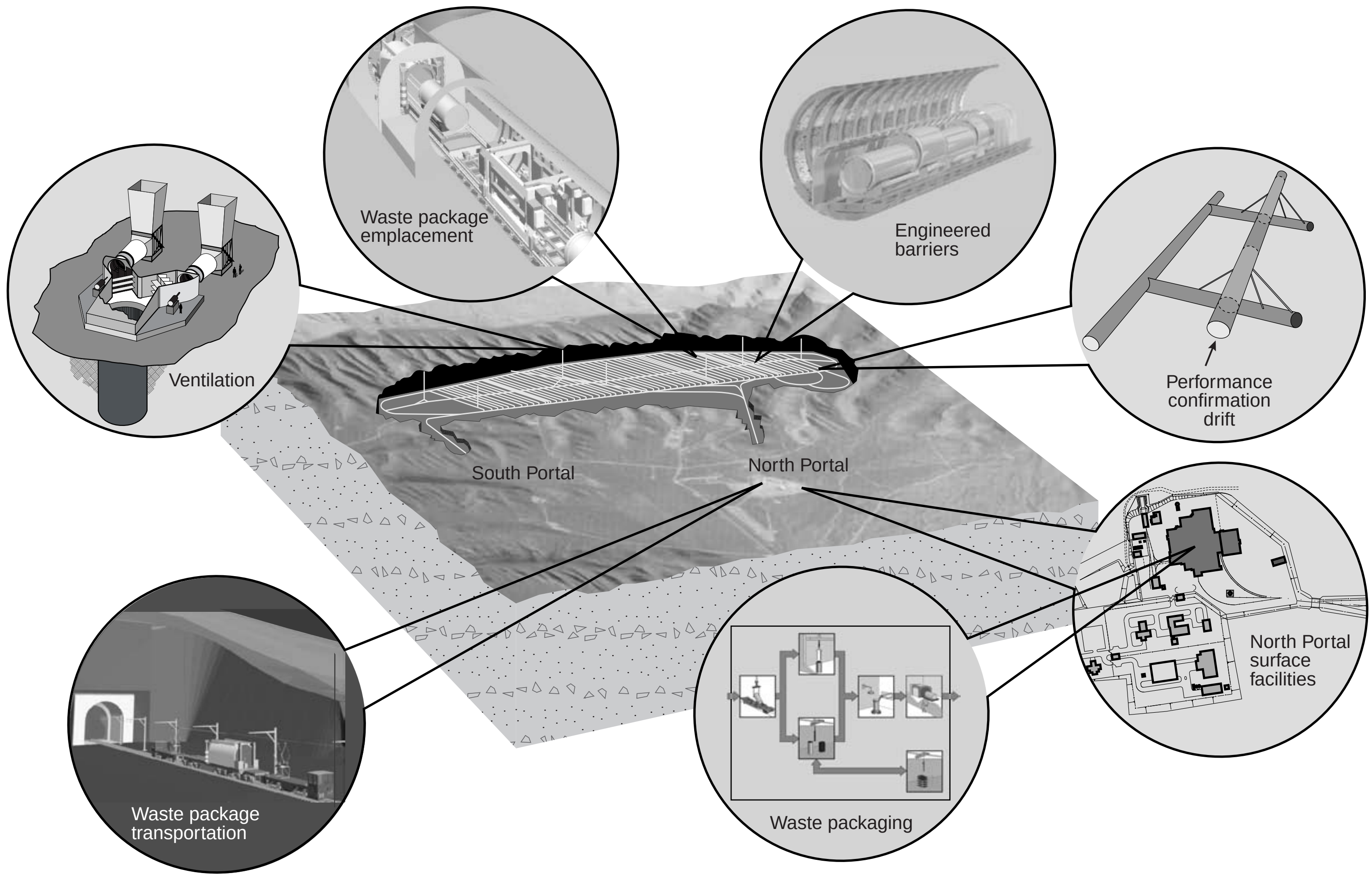
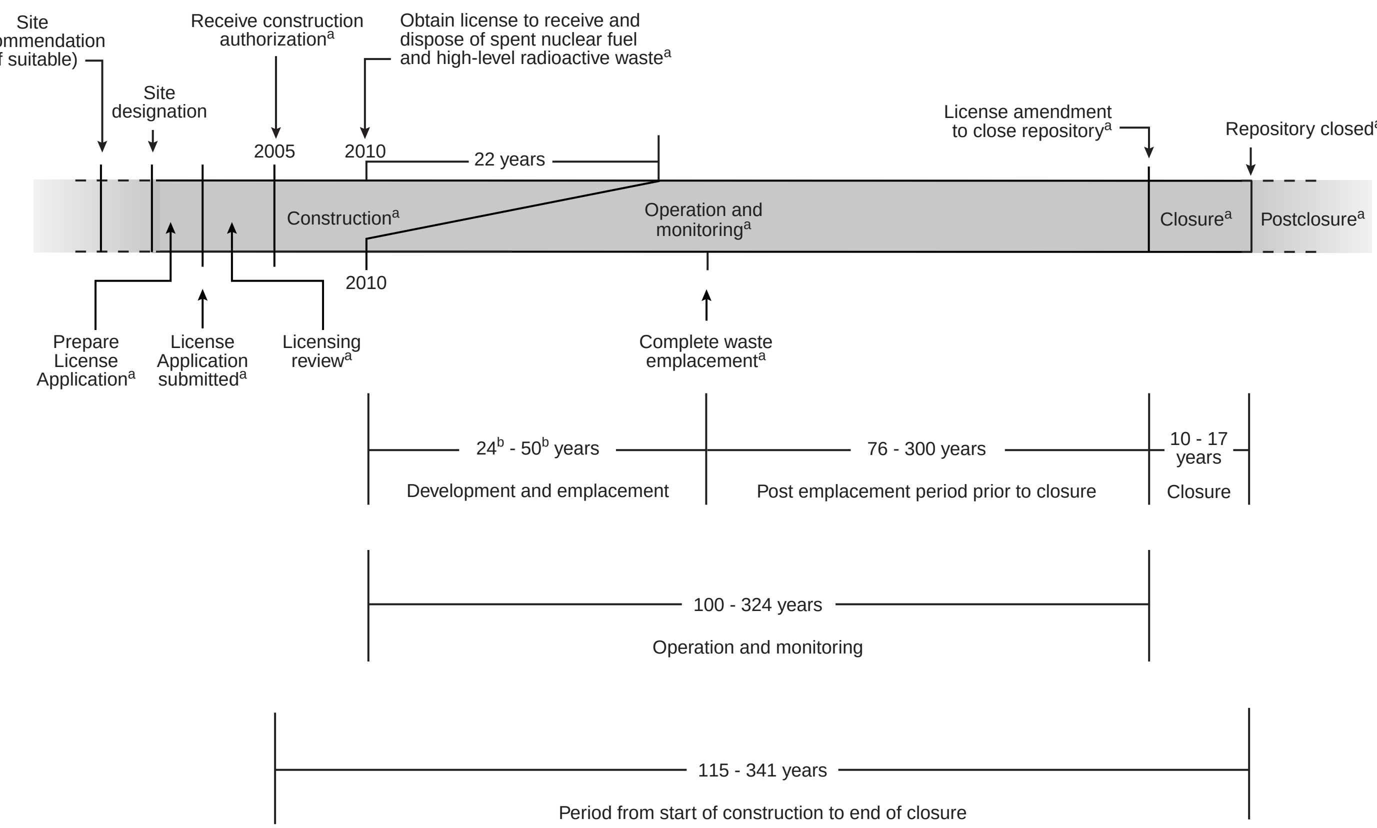


Figure 2-32. Typical independent spent fuel storage installation.



Source: Modified from DIRS 153849-DOE (2001, Figure 2-1).

Figure 2-8. Artist's conception of proposed repository facilities.



a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 2-9. Monitored geologic repository range of milestones used for analysis.

Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or heavy-haul truck with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

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101214	CRWMS M&O 1996	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1996. *Nevada Potential Repository Preliminary Transportation Strategy Study 2.* B00000000-01717-4600-00050 REV 01. Two volumes. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960724.0199; MOL.19960724.0200. In the Draft EIS, this reference was cited as TRW 1996 in Chapter 12.
104849	CRWMS M&O 1997	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1997. *Intermodal Transfer Station Preliminary Design.* BCBI00000-01717-0200-00007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980303.0029. In the Draft EIS, this reference was cited as TRW 1997d in Chapter 12.
154448	CRWMS M&O 1998	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1998. *Road Upgrades for Heavy Haul Truck Routes.* BCBI00000-01717-0200-00008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981207.0254.
154816	CRWMS M&O 1998	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1998. *Yucca Mountain Project Transportation EIS Maps, IMT Maps.* BCB100000-01717-0200-00007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981207.0252.
102030	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1999. *Waste Package Final Update to EIS Engineering File.* BBA000000-01717-5705-00019 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990330.0530. In the Draft EIS, this reference was cited as TRW 1999c in Chapter 12.
104508	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1999. *Repository Surface Design Engineering Files Report.* BCB000000-01717-5705-00009 REV 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990615.0238. In the Draft EIS, this reference was cited as TRW 1999a in Chapter 12.
104523	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1999. *Engineering File - Subsurface Repository.* BCA000000-01717-5705-00005 REV 02 DCN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990621.0157; MOL.19990615.0230. In the Draft EIS, this reference was cited as TRW 1999b in Chapter 12.
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150941	CRWMS M&O 2000	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 2000. *FEIS Update to Engineering File - Subsurface Repository.* TDR-EBS-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000612.0058.
152010	CRWMS M&O 2000	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 2000. *Repository Surface Design Engineering Files Report Supplement.* TDR-WHS-EV-000001 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000626.0025.
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101779	DOE 1998	DOE (U.S. Department of Energy) 1998. *Viability Assessment of a Repository at Yucca Mountain.* DOE/RW-0508. Overview and five volumes. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981007.0027; MOL.19981007.0028; MOL.19981007.0029; MOL.19981007.0030; MOL.19981007.0031; MOL.19981007.0032.
153255	DOE 2001	DOE (U.S. Department of Energy) 2001. *Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program.* DOE/RW-0533. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010802.0217.
153849	DOE 2001	DOE (U.S. Department of Energy) 2001. *Yucca Mountain Science and Engineering Report.* DOE/RW-0539. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272.
155982	DOE 2001	DOE (U.S. Department of Energy) 2001. *Site Characterization Progress Report: Yucca Mountain, Nevada.* Number 23. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010412.0099.
156899	DOE 2001	DOE (U.S. Department of Energy) 2001. *Cost Escalation and Interest Rates.* TDR-CRW-SE-000019 REV 00. Washington, D.C.: Bechtel SAIC Co., LLC. ACC: MOV.20011106.0002.

156900	DOE 2001	DOE (U.S. Department of Energy) 2001. *Life Cycle Cost Analysis for Repository Flexible Design Concepts.* TDR-CRW-SE-000017 REV 00. Washington, D.C.: Bechtel SAIC Co., LLC. ACC: MOL.20011120.0951.
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100018	National Research Council 1995	National Research Council 1995. *Technical Bases for Yucca Mountain Standards.* Washington, D.C.: National Academy Press. TIC: 217588.

101899	NRC 1996	NRC (U.S. Nuclear Regulatory Commission) 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Main Report, Final Report.* NUREG-1437, Vol. 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233963.
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156055	UER 2001	UER (Urban Environmental Research) 2001. *Property Value Impacts from the Shipment of High-Level Nuclear Waste through Clark County, Nevada.* Scottsdale, Arizona: Urban Environment Research, LLC. TIC: 250920.
101941	USN 1996	USN (U.S. Department of the Navy) 1996. *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel.* DOE/EIS-0251. [Washington, D.C.]: U.S. Department of Energy. TIC: 227671.
104792	YMP 1990	YMP (Yucca Mountain Site Characterization Project) 1990. *Preliminary Rail Access Study.* YMP/89-16. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19980817.0094. In the Draft EIS, this reference was cited as TRW 1999d in Chapter 12.
104737	YMP 1997	YMP (Yucca Mountain Site Characterization Project) 1997. *Location of Alternative Heavy-Haul Routes and Future Las Vegas Beltway.* YMP-97-262.0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990610.0306. In the Draft EIS, this reference was cited as DOE 1997c in Chapter 12.
104560	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Potential Rail Alignments.* YMP/98-104.0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990526.0034. In the Draft EIS, this reference was cited as DOE 1998f in Chapter 12.
104588	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Nevada Routes for Heavy-Haul Truck Shipments of SNF and HLW to Yucca Mountain.* YMP/97-263.9. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990526.0035. In the Draft EIS, this reference was cited as DOE 1998g in Chapter 12.
104743	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Nevada Routes for Legal-Weight Truck Shipments of SNF and HLW to Yucca Mountain.* YMP/97-310.3. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990526.0033. In the Draft EIS, this reference was cited as DOE 1998d in Chapter 12.

104853	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Potential Rail Corridors.* YMP/98-179.0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990526.0032. In the Draft EIS, this reference was cited as DOE 1998e in Chapter 12.

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3. AFFECTED ENVIRONMENT

To analyze potential environmental impacts that could result from the implementation of the Proposed Action, the U.S. Department of Energy (DOE) has compiled extensive information about the environments that could be affected. The Department used this information to establish the *baseline* against which it measured potential impacts (see Chapter 4). Chapter 3 describes (1) environmental conditions that will exist at and in the region of the proposed repository site at Yucca Mountain after the conclusion of site characterization activities (Section 3.1); (2) environmental conditions along the proposed transportation corridors in Nevada that DOE could use to ship spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site (Section 3.2); and (3) environmental conditions at the 72 commercial and 5 DOE sites in the United States that manage spent nuclear fuel and high-level radioactive waste (Section 3.3).

DOE obtained baseline environmental information from many sources. These sources included reports and studies sponsored by DOE, other Federal agencies (for example, the U.S. Geological Survey), and the State of Nevada and affected units of local government. Affected units of local government include Nye County, which is the county in which the repository site is located, by DOE decision as allowed under the Nuclear Waste Policy Act, as amended (this EIS refers to the amended Act as the NWPA), counties contiguous to Nye County (that is, Clark, Lincoln, White Pine, Eureka, Lander, Churchill, Mineral, and Esmeralda Counties in Nevada and Inyo County in California). In addition, DOE has sought input from Elko County, Nevada, which could be affected by transportation activities associated with the Proposed Action.

DOE received reports from the State of Nevada and affected units of local government during the EIS scoping process, informally from local government personnel, and formally during ongoing interactions between DOE and State and local governments. The subjects of these reports include socioeconomics, cultural resources, hydrology, transportation planning and emergency response, and resource supply. DOE evaluated these reports and, where appropriate, they are discussed in individual resource area sections of the EIS.

3.1 Affected Environment at the Yucca Mountain Repository Site at the Conclusion of Site Characterization Activities

To define the existing environment at and in the region of the proposed repository, DOE has compiled environmental baseline information for 13 subject areas. This environment includes the manmade structures and physical disturbances from DOE-sponsored site selection studies (1977 to 1988) and site characterization studies (1989 to 2001) to determine the suitability of the site for a repository. This chapter and supporting documents, called *environmental baseline files,* contain baseline information for:

- *Land use and ownership:* Land-use practices and land ownership information in the Yucca Mountain region (Section 3.1.1)

- *Air quality and climate:* The quality of the air in the Yucca Mountain region and the area's climatic conditions (temperature, precipitation, etc.) (Section 3.1.2)

- *Geology:* The geologic characteristics of the Yucca Mountain region both at and below the ground surface, the frequency and severity of seismic activity, volcanism, and mineral and energy resources (Section 3.1.3)

- *Hydrology:* Surface-water and groundwater features in the Yucca Mountain region and the quality of the water (Section 3.1.4)

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- *Biological resources and soils:* Plants and animals that live in the Yucca Mountain region, the occurrence of special status species and *wetlands*, and the kinds and quality of soils in the region (Section 3.1.5)

- *Cultural resources:* Historic and archaeological resources in the Yucca Mountain region, the importance those resources hold, and for whom (Section 3.1.6)

- *Socioeconomic environment:* The labor market, population, housing, some public services, real *disposable income*, *gross regional product*, government spending, and DOE payment equal to taxes in the Yucca Mountain region (Section 3.1.7)

- *Occupational and public health and safety:* The levels of radiation that occur naturally in the Yucca Mountain air, soil, animals, and water; radiation dose estimates for Yucca Mountain workers from *background radiation*; radiation exposure, dispersion, and accumulation in air and water for the Nevada Test Site area from past nuclear testing and current operations; and public radiation dose estimates from background radiation (Section 3.1.8)

- *Noise and Vibration:* Noise and vibration sources and levels of noise and vibration that commonly occur in the Yucca Mountain region during the day and at night, and the applicability of Nevada standards for noise in the region (Section 3.1.9)

- *Aesthetics:* The visual resources of the Yucca Mountain region in terms of land formations, vegetation, and color, and the occurrence of unique natural views in the region (Section 3.1.10)

- *Utilities, energy, and materials:* The amount of water available for the Yucca Mountain region, water-use practices, water sources, the demand for water at different times of the year, the amounts of power supplied to the region, the means by which power is supplied, and the availability of natural gas and propane (Section 3.1.11)

- *Waste and hazardous materials:* Ongoing solid and hazardous waste and wastewater management practices at Yucca Mountain, the kinds of waste generated by current activities at the site, the means by which DOE disposes of its waste, and DOE recycling practices (Section 3.1.12)

- *Environmental justice:* The locations of *low-income* and *minority populations* in the Yucca Mountain region and the income levels among low-income populations (Section 3.1.13)

DOE evaluated the existing environments in regions of influence for each of the 13 subject areas. Table 3-1 defines these regions, which are specific to the subject areas in which DOE could reasonably expect to predict impacts, if any, related to the proposed repository. Human health risks from exposure to airborne *contaminant* emissions were assessed for an area within approximately 80 kilometers (50 miles), and economic effects, such as job and income growth, were evaluated in a three-county socioeconomic region.

In the past, the vicinity around Yucca Mountain has been the subject of a number of studies in support of mineral and energy resource exploration, nuclear weapons testing, and other DOE activities at the Nevada Test Site. From 1977 to 1988, the Yucca Mountain Project performed studies to assist in the site selection process for a repository. These studies, which involved the development of roads, drill holes, trenches, and seismic stations, along with non-Yucca Mountain activities, disturbed about 2.5 square kilometers (620 acres) of land in the vicinity of Yucca Mountain (DIRS 104854-YMP 1998, p. 1). Yucca Mountain site characterization activities began in 1989 and continued through 2001. These activities include surface excavations, excavations of exploration shafts, subsurface excavations and borings, and testing to evaluate the suitability of Yucca Mountain as the site for a repository. As of 2001, these activities have

Table 3-1. Regions of influence for the proposed Yucca Mountain Repository.

Subject area	Region of influence
Land use and ownership	Land around site of proposed repository that DOE would disturb and over which DOE would need to obtain control; analyzed land withdrawal area is 600 square kilometers[a] (Section 3.1.1).
Air and climate	An approximate 80-kilometer[b] radius around Yucca Mountain, and at boundaries of controlled lands surrounding Yucca Mountain (Section 3.1.2).
Geology	The regional geologic setting and the specific geology of Yucca Mountain (Section 3.1.3).
Hydrology	*Surface water:* construction areas that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of the repository that would be affected by eroded soil or potential spills of contaminants.
	Groundwater: aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction, and aquifers downstream of the repository that repository use or long-term releases from the repository could affect (Section 3.1.4).
Biological resources and soils	Area that contains all potential surface disturbances resulting from the Proposed Action (described in Chapter 2) plus some additional area to evaluate local animal populations; roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (Section 3.1.5).
Cultural resources	Land areas that repository activities would disturb (described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur (Section 3.1.6).
Socioeconomic environment	Three Nevada counties (Clark, Lincoln, and Nye) in which repository activities could most influence local economies and populations (Section 3.1.7).
Occupational and public health and safety	An approximate 80-kilometer radius around Yucca Mountain and at the approximate boundary of analyzed land withdrawal area (Section 3.1.8).
Noise and vibration	Existing residences in the Yucca Mountain region and at the approximate edge of the analyzed land withdrawal area (Section 3.1.9).
Aesthetics	Approximate boundary of analyzed land withdrawal area (Section 3.1.10).
Utilities, energy, and materials	Public and private resources on which DOE would draw to support the Proposed Action (for example, private utilities, cement suppliers) (Section 3.1.11).
Waste and hazardous materials	On- and offsite areas, including landfills and hazardous and radioactive waste processing and disposal sites, in which DOE would dispose of site-generated repository waste (Section 3.1.12).
Environmental justice	Varies with the different subject areas. The environmental justice regions of influence will correspond to those of the specific subject areas, as defined in this table (Section 3.1.13).

a. 600 square kilometers = about 150,000 acres or 230 square miles.
b. 80 kilometers = about 50 miles.

disturbed about an additional 1.5 square kilometers (370 acres) in the vicinity of Yucca Mountain (DIRS 104508-CRWMS M&O 1999, Table 6-2). Reclamation activities have started and will continue to occur as sites are released from further study.

The existing environment at Yucca Mountain includes the Exploratory Studies Facility, which includes the tunnel (drift), the North and South Portal pads and supporting structures, an excavated rock storage area, a topsoil storage area, borrow pits, boreholes, trenches, roads, and supporting facilities and disturbances for site characterization activities. Table 3-2 lists facilities, structures, equipment, and disturbances at Yucca Mountain and at the central support site in Area 25 of the Nevada Test Site. Area 25 was used in the early 1960s by the Atomic Energy Commission (a DOE predecessor agency) and the National Aeronautics and Space Administration as part of a program to develop nuclear reactors for use in the Nation's space program. The former Nuclear Rocket Development Station administrative areas complex in Area 25 has become the Yucca Mountain Site Characterization Central Support Site. As noted in the table, several of the Area 25 functions have been relocated to the North Portal site since the publication of the Draft EIS.

Table 3-2. Existing facilities, structures, and disturbances at Yucca Mountain.[a]

Yucca Mountain	Area 25 Central Support Site
Exploratory Studies Facility (North Portal pad and supporting structures)	Field Operations Center (moved)[b]
Exploratory Studies Facility (South Portal pad)	Hydrologic research facility
Cross drift[c]	Sample management facility and warehouse
Concrete batch plant and precast yard	Radiological studies facility (moved)[b]
Fill borrow pits (3) and screening plants	Meteorology/air quality studies facility (moved)[b]
Subdock equipment storage facility	Project accumulation area for hazardous waste
Equipment/supplies laydown yard	Gas station
Hydrocarbon management facility	Maintenance facility
Boxcar equipment and supplies yard	U.S. Geological Survey technical warehouse (moved)[b]
Water wells J-12 and J-13	Tunnel rescue facility
Excavated rock storage pile	Sewage lagoon operated by the Nevada Test Site
Topsoil storage pile	
Explosives storage magazines (2)	
Water booster pump and distribution system	
Boreholes (about 300)	
Trenches and test pits (about 200)	
Busted Butte geologic test drift	
Fran Ridge heated-block test facility	
Water infiltration test sites	
Meteorological monitoring towers	
Air quality monitoring sites	
Radiological monitoring sites	
Ecological study plots	
Reclamation study plots	
Septic system	
Roads	

a. Source: Modified from DIRS 148111-CRWMS M&O (1998, all) and DIRS 155933-Jacobs (2001, all).
b. These functions have been relocated to the North Portal site since the Draft EIS was published.
c. Drift is a mining term for a horizontal tunnel.

DOE has made revisions to this section since the Draft EIS to present newly acquired information that contributes to an improved (or updated) understanding of the potentially *affected environment* at Yucca Mountain and its region, and to include information and suggestions for improvement provided through public comments on the Draft EIS and the Supplement to the Draft EIS. The following items summarize key changes to the EIS that deal with the affected environment at the Yucca Mountain site:

- Corrections and updates were made to *land use* figures and text, including changes to the breakout of Nevada land by controlling authority to be consistent with recent land transactions. Clarification was provided on the statutory requirements associated with the proposed land withdrawal, on the rationale for the size of the withdrawal, and on the breakout of the agencies with administrative authority over the land.

- *Air quality and climate* text was modified to better describe the attainment status of areas outside the region of influence and to discuss Federal agency responsibilities under the *conformity* provisions of the Clean Air Act. A new section was added to describe paleoclimatology studies that have been performed as part of the Yucca Mountain Project.

- Minor text changes, including facts and figures, were made to both the *geology* and *hydrology* discussions in response to comments and to ensure consistency with updated information in the new primary source document, the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, all). Several geology and hydrology figures were improved with better graphics or additional information, and several figures were added.

- A new *geology* discussion was added on the formation and characteristics of fractures found in the rock at Yucca Mountain. An update was added to describe the status of ongoing efforts to monitor crustal strain rates in the area.

- Text was added or modified in *hydrology* discussions to better describe the direction of groundwater and the lack of water observed in the subsurface during tunneling at Yucca Mountain, and to provide information on the Devils Hole National Monument and on Nevada Test Site groundwater modeling efforts. Updates were added to describe the status of ongoing efforts to collect additional hydrologic information, including those resulting from the cooperative agreement between Nye County and DOE to investigate the groundwater flow system downgradient of Yucca Mountain. Updates were also added to discuss efforts to validate and verify chlorine-36 study results, and to study postulated evidence of past upwelling of the water table.

- The *biological resources* discussion of plant species in the area of Yucca Mountain was expanded to include identification of exotic species. Text was modified to describe more accurately the opposing viewpoint expressed by the State of Nevada with respect to the biological studies performed as part of the Yucca Mountain Project.

- *Socioeconomics* text and indicator numbers were revised to incorporate updated information from State of Nevada and local agency population estimates. Text was added to explain the basis for using these numbers rather than numbers anchored in 2000 Census data that became available since the publication of the Draft EIS. Socioeconomic indicator data (Gross Regional Product, government spending, and real disposable income) were added and discussions in several key areas were expanded to include estimates of socioeconomic indicators to 2035.

- The region of influence population *distribution* presented in the *occupational and public health and safety* discussion was changed to the new population estimates and is now described for both 2000 and 2035. The discussion of natural radiation sources was revised for clarity and accuracy. Tables and text were revised to better describe background/baseline radiation exposures and their effects at Yucca Mountain, in Nevada, and at other sites in the United States. A new section was added to discuss regional effects from past weapons testing at the Nevada Test Site.

- New text and a new table were added to the *noise* discussions to introduce the concept of vibration as an element of environmental assessment. The existing discussion of noise was augmented with a description of noise threshold levels that present hearing hazards as opposed to annoyance.

- Clarifying text was added to the *aesthetics* section's discussion of the Bureau of Land Management Visual Resource Management system, and particularly for the system's scenic quality component. Text was added describing nighttime darkness as an element of aesthetics for the Yucca Mountain region.

- Updated information was included in discussions of *utilities, energy, and site services*, as well as for *waste and hazardous materials*.

- *The environmental justice* discussion was expanded to better described the evaluation methodology and updated to incorporate 2000 Census data on minority communities. (The 1990 Census data still represents the most current available data for low-income communities.)

3.1.1 LAND USE AND OWNERSHIP

The *region of influence* for land use and ownership includes land at the site of the proposed repository that DOE would not disturb and the lands that surround the site of the proposed repository over which DOE would have to obtain permanent control to operate the repository. The Department has compiled land-use and ownership information for this region. Most of the land in the region is managed by agencies of the Federal Government. Sections 3.1.1.1 and 3.1.1.2 discuss land use and ownership for the region of influence and for a larger area around Yucca Mountain. Section 3.1.1.3 describes the *analyzed land withdrawal area* for the repository. Section 3.1.1.4 discusses Native American views about the ownership of the land around Yucca Mountain. The Environmental Baseline File for Land Use (DIRS 104993-CRWMS M&O 1999, all) is the basis of the information in this section unless otherwise noted.

3.1.1.1 Regional Land Use and Ownership

The Federal Government manages more than 85 percent of the land in Nevada (about 240,000 square kilometers or 93,000 square miles). Most of this land is under the control of the Bureau of Land Management (which is part of the U.S. Department of the Interior), the U.S. Department of Defense, and DOE. The remainder of the Federally managed land is primarily under the jurisdiction of the Forest Service, which is part of the U.S. Department of Agriculture, with smaller areas under the control of the National Park Service and the Bureau of Reclamation, both of which are parts of the Department of the Interior. About 42,000 square kilometers (16,000 square miles) are under State, local, or private ownership, and about 5,000 square kilometers (2,000 square miles) are Native American lands. Table 3-3 summarizes Nevada land holdings and the controlling authority. Figure 3-1 shows ownership and use of lands around the site of the proposed repository.

The Nevada Test Site, which is a DOE facility, covers about 3,700 square kilometers (1,400 square miles). The Atomic Energy Commission, a DOE predecessor agency, established the Nevada Test Site in the 1950s to test nuclear devices. More information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all). The U.S. Air Force operates the Nellis Air Force Range [its name recently changed to the Nevada Test and Training Range (DIRS 157220-BLM 2001, all)], which covers about 12,000 square kilometers (4,500 square miles) and is one of the largest and most active military training ranges in the United States. More information on current and future uses of the Nellis Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all). The Military Lands Withdrawal Act of 1999, approved by the passage of Public Law 106-65 on October 5, 1999, went into effect on

Table 3-3. Nevada land areas and controlling authorities (square kilometers).[a,b]

Authority	Area	Percentage[c]
State, local, county, or private	42,000	15
Bureau of Land Management	194,000	68
Department of Defense	13,000	5
Department of Energy	3,700	1
Other Federal authorities	26,000	9
Native American tribes	5,000	2

a. Source: DIRS 104993-CRWMS M&O (1999, p. 1); DIRS 103472-USAF (1999, pp. 2-8 to 2-10); and DIRS 154121-DOI (2000, Volume I, p. 19)
b. To convert square kilometers to square miles, multiply by 0.3861.
c. Percentages calculated from area numbers prior to rounding and are shown to the nearest 1 percent.

November 6, 2001 and extended the affected land withdrawal until November 6, 2021. Actions taken under the Act at the Nellis Range also affected lands managed by the Bureau of Land Management and the Department of Energy (DIRS 103472-USAF 1999, pp. 2-8 to 2-10). Approximately 140 and 520 square kilometers (55 and 200 square miles) of land were transferred from the Department of Defense (that is, the Nellis Range) to the Bureau of Land Management (for public use) and DOE, respectively. Approximately 160 square kilometers (60 square miles) of land formerly withdrawn for use by DOE was transferred to the Department of Defense. The Nevada land areas and controlling authorities summarized in Table 3-3 incorporate these changes.

The region has special-use areas, which generally are excluded from development that would require terrain alterations unless such alterations would benefit wildlife or public recreation. The Fish and Wildlife Service of the U.S. Department of the Interior manages the Desert National Wildlife Range and the Ash Meadows National Wildlife Refuge, which are about 50 kilometers (30 miles) east and 39 kilometers (24 miles) south of Yucca Mountain, respectively (Figure 3-1). These areas provide *habitat* for a number of resident and migratory animal species in relatively undisturbed natural ecosystems. The National Park Service manages Death Valley National Park, which is in California and Nevada approximately 35 kilometers (22 miles) southwest of Yucca Mountain. The small enclave of Devils Hole Protective Withdrawal in Nevada adjacent to the east-central boundary of Ash Meadows is also administered by the National Park Service (Figure 3-1). The Timber Mountain *Caldera* National Natural Landmark is located primarily on the Nellis Air Force Range and the Nevada Test Site. The Landmark is just north of the proposed repository withdrawal area. The Timber Mountain Caldera is also designated as an Area of Critical Environmental Concern (DIRS 157220-BLM 2001, p. 2-9).

> **CALDERA**
>
> A volcanic crater that has a diameter many times that of the vent. It is formed by collapse of the central part of a volcano or by explosions of extraordinary violence. The erupted materials are commonly spread over great distances beyond the caldera. Volcanic debris that erupted from the Timber Mountain and other calderas north of Yucca Mountain formed the southwestern Nevada volcanic field of which the volcanic rocks at Yucca Mountain are a part.

There is virtually no State-owned land immediately adjacent to the repository site. There are scattered tracts of private land in and near communities such as Beatty and Indian Springs in Nevada. There are also larger private tracts in the Las Vegas Valley, around Pahrump, and in the south-central portion of the large area that makes up Amargosa Valley. The closest year-round housing is at what was once referred to as Lathrop Wells, about 22 kilometers (14 miles) south of the site. This location is now part of the unincorporated Town of Amargosa Valley. There is farming—primarily grasses and legumes—for hay and dairy operations about 30 kilometers (19 miles) south of the proposed repository (Figure 3-1).

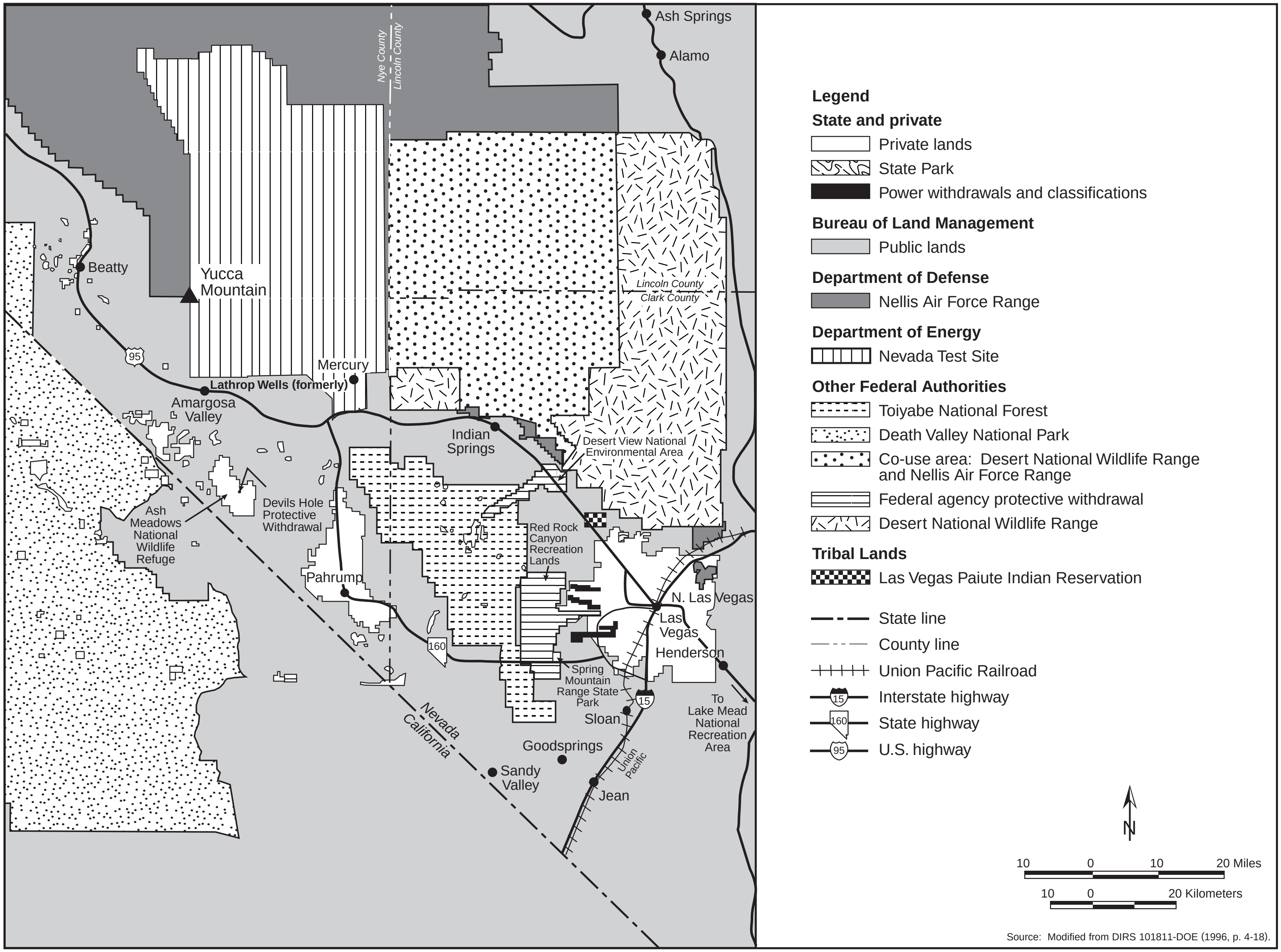

Figure 3-1. Land use and ownership in the Yucca Mountain region.

3.1.1.2 Current Land Use and Ownership at Yucca Mountain

DOE has established land-use agreements to support its site characterization activities at Yucca Mountain. The Yucca Mountain Site Characterization Zone (Figure 3-2) includes DOE, Bureau of Land Management, and Air Force lands.

The Bureau of Land Management granted DOE a right-of-way reservation (N-47748) for Yucca Mountain site characterization activities (DIRS 102218-BLM 1988, all). This reservation comprises 210 square kilometers (52,000 acres). The land in this reservation is open to public use, with the exception of about 20 square kilometers (5,000 acres) near the site of the proposed repository that were withdrawn in 1990 from the mining and mineral leasing laws to protect the physical integrity of the repository block (P.L. Order 6802, "Withdrawal of Public Land to Maintain the Physical Integrity of the Subsurface Environment, Yucca Mountain Project"). The lands in this reservation not withdrawn from the mining and mineral leasing laws contain a number of unpatented mining claims (lode and placer). In addition, there is one patented mining claim surrounded by the reservation. Patented Mining Claim No. 27-83-0002 covers 0.8 square kilometer (200 acres) to mine volcanic cinders used as a raw material in the manufacture of cinderblocks.

The Bureau of Land Management manages surface resources on the Nellis Air Force Range. In 1994, the Bureau granted DOE a right-of-way reservation (N-48602) to use about 75 square kilometers (19,000 acres) of Nellis land for Yucca Mountain site characterization activities (DIRS 102219-BLM 1994, all). This land, which is closed to public access and use, has been studied extensively. Many of the exploratory facilities are on Nellis land.

The Yucca Mountain Site Characterization Office and the DOE Nevada Operations Office have a management agreement that allows the use of about 230 square kilometers (58,000 acres) of Nevada Test Site land for site characterization activities. The Land Facility Use Management Policy under the Memorandum of Agreement with the Nevada Test Site gives the Yucca Mountain Project technical responsibility independent of, but in coordination with, environmental activities at the Nevada Test Site. The Yucca Mountain Project is in compliance with the agreement, which requires it to meet the same environmental requirements that apply to the Nevada Test Site.

3.1.1.3 Potential Repository Land Withdrawal

Nuclear Regulatory Commission initial licensing conditions for a monitored geologic repository (10 CFR Part 60) have been modified under 10 CFR Part 63 to include risk-informed, performance-based environmental regulations. These conditions include a requirement that the lands for which DOE is seeking a repository license be either acquired and under the jurisdiction and control of DOE or be permanently withdrawn and reserved for its use. As noted, portions of the lands being used for site characterization that would be required for the repository are controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office. Because all of these lands are not under permanent DOE control, a land withdrawal would be required.

The procedure for land withdrawal is the method by which the Federal Government places exclusive control over land it owns with a particular agency for a particular purpose. Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Congress can authorize and direct a permanent withdrawal of lands such as those required for the proposed repository at Yucca Mountain. The extent and conditions of the withdrawal would be determined by Congress. The extent of a land withdrawal area is important to the analysis and understanding of the impacts of the Proposed Action. For example, the magnitude of impacts to a member of the public from an accident at an operating repository would be determined in part by the proximity of the land withdrawal boundary to

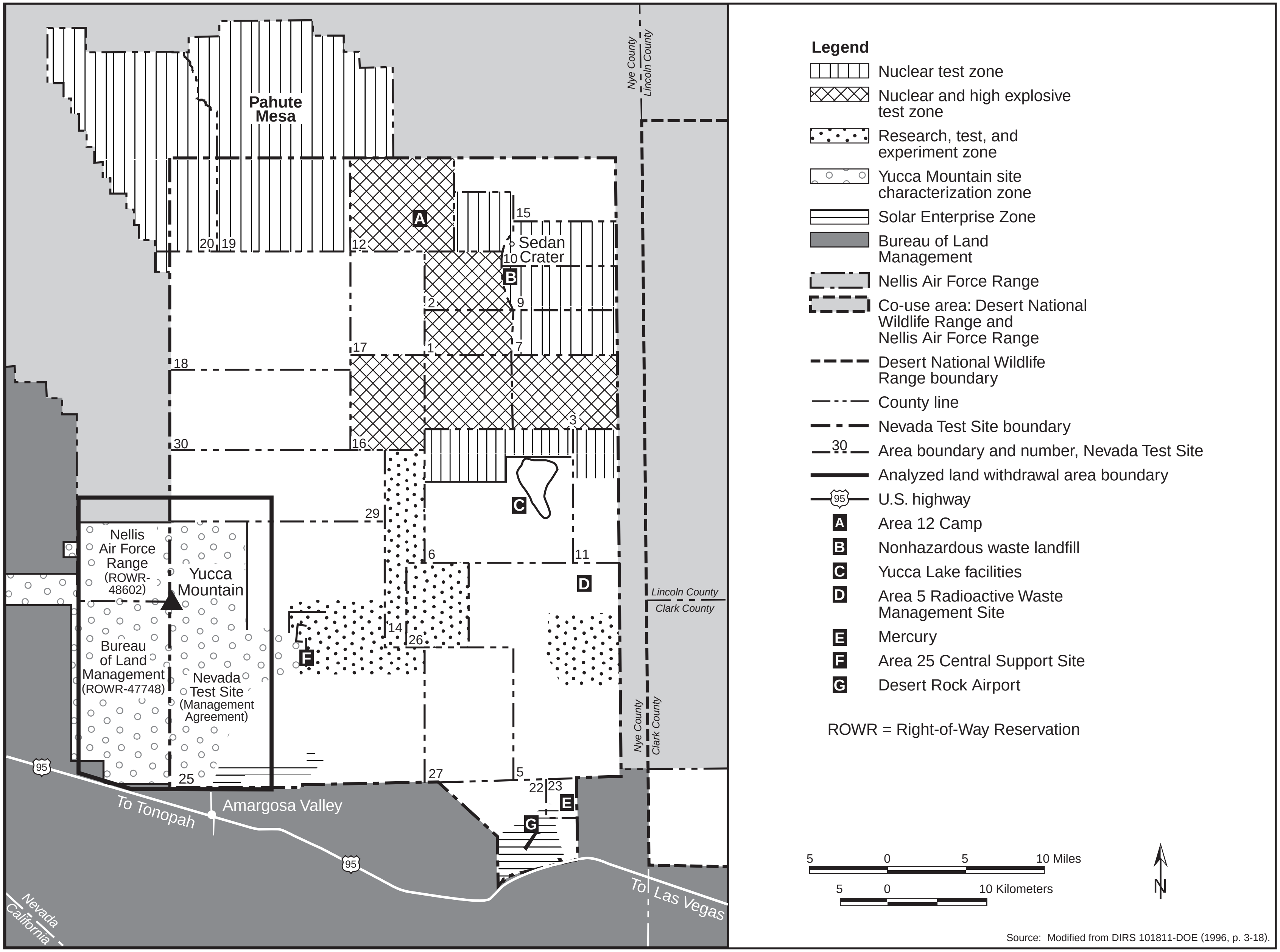

Figure 3-2. Land use and ownership in the analyzed land withdrawal area and vicinity.

the repository operations areas. As a consequence, DOE used a conservative land withdrawal area to extend control toward the closest populated area, the Town of Amargosa Valley, Nevada, thus preventing future encroachment as the basis for analysis in this EIS. The identification of either a restricted or *controlled area* boundary would be defined as part of the licensing process, if there was a determination to proceed with the Yucca Mountain Repository.

Figure 3-2 shows the land withdrawal area analyzed in this EIS that encompasses the current right-of-way reservations for site characterization. This area includes about 600 square kilometers (150,000 acres) of land. The land in this area is currently under the control of the Air Force, DOE, and the Bureau of Land Management (Table 3-4). Approximately 180 square kilometers (45,000 acres) of Bureau of Land Management land in the southwestern portion of the withdrawal area overlaps the taxing district for the unincorporated Town of Amargosa Valley, Nevada. This taxing district, described under Section 18.04.010 of the Nye County Code and Nye County Ordinance 136, encompasses approximately 1,300 square kilometers (320,000 acres). The 180 square kilometers of overlap is Federal land that the Bureau of Land Management administers as public land under a multiple-use classification that the Federal Government has not conveyed to a municipality.

Table 3-4. Current land administration and public accessibility to the analyzed land withdrawal area.[a,b]

Agency	Area (square kilometers)[c]	Current accessibility
DOE (Nevada Test Site)	320	No public access
U.S. Air Force (Nellis Air Force Range)	96	No public access
Bureau of Land Management (public land)	180	Public access
Private land (one patented mining claim)	1	No public access

a. Source: DIRS 153650-YMP (1998, all); DIRS 101521-BLM (1992, all).
b. A description of the area by township, range, and section is available from DOE, Las Vegas, Nevada.
c. To convert square kilometers to square miles, multiply by 0.3861; to convert to acres, multiply by 247.1.

Most of the land controlled by the Bureau of Land Management in the analyzed land withdrawal area is associated with the current right-of-way reservation (N-47748) for Yucca Mountain site characterization activities. This land is open to public use, with the exception of about 20 square kilometers (5,000 acres) near the site of the proposed repository that are withdrawn from the mining and mineral leasing laws and an existing patented mining claim (No. 27-83-0002). The lands open to public use also contain a number of unpatented mining claims (lode and placer). Off-road vehicle use is permitted in these lands. There is a designated utility corridor in the southern portion of these lands.

More detailed descriptions of the land under the control of the Bureau of Land Management in the region of Yucca Mountain are available in the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

3.1.1.4 Native American Treaty Issue

One Native American ethnic group with cultural and historic ties to the Yucca Mountain region is the Western Shoshone. A special concern of the Western Shoshone people is the Ruby Valley Treaty of 1863. The Western Shoshone people maintain that the treaty gives them rights to 97,000 square kilometers (24 million acres) in Nevada, including the Yucca Mountain region (DIRS 102216-Western Shoshone v. United States 1997, all). The legal dispute over the land began in 1946 when the Indian Claims Commission Act gave tribes the right to sue the Federal Government for unkept treaty promises. If a tribe were to win a claim against the Government, the Act specifies that the tribe could receive only a monetary award and not land or other remunerations.

The Western Shoshone people filed a claim in the early 1950s alleging that the Government had taken their land. The Indian Claims Commission found that Western Shoshone title to the Nevada lands had gradually extinguished and set a monetary award as payment for the land. In 1976, the Commission entered its final award to the Western Shoshone people, who dispute the Commission findings and have not accepted the monetary award for the lands in question. They maintain that a settlement has not been reached (the U.S. Treasury is holding these monies in an interest-bearing account) and that Yucca Mountain is on Western Shoshone land. A 1985 U.S. Supreme Court decision (DIRS 148197-United States v. Dann 1985, all) ruled that even though the money has not been distributed, the United States has met its obligations with the Commission's final award and, as a consequence, the aboriginal title to the land had been extinguished.

3.1.2 AIR QUALITY AND CLIMATE

The region of influence for air quality is an area within a radius of about 80 kilometers (50 miles) around the site of the proposed repository and at the boundaries of controlled lands around Yucca Mountain. This region encompasses portions of Esmeralda, Clark, Lincoln, and Nye Counties in Nevada and a portion of Inyo County, California. To determine the air quality and climate for the Yucca Mountain region, DOE site characterization activities have included the monitoring of air quality and meteorological conditions. The Department has monitored the air for gaseous *criteria pollutants* (*carbon monoxide,* nitrogen dioxide, *ozone*, and *sulfur dioxide*) and for *particulate matter*. This section describes the existing air quality and climate at the proposed repository site and in the surrounding region. Sections 3.1.2.1 and 3.1.2.2 describe the air quality and climate, respectively. Unless otherwise noted, the *Environmental Baseline File for Meteorology and Air Quality* (DIRS 102877-CRWMS M&O 1999, all) is the basis for the information provided in this section.

3.1.2.1 Air Quality

Air quality is determined by measuring concentrations of certain pollutants in the atmosphere. The U.S. Environmental Protection Agency designates an area as being *in attainment* for a particular pollutant if *ambient* concentrations of that pollutant are below National *Ambient Air Quality Standards* (Table 3-5). (*Ambient air* is that part of the atmosphere outside buildings to which the general public has access.) The Environmental Protection Agency established the national standards, as directed by the Clean Air Act, to define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). The standards specify the maximum pollutant concentrations and frequencies of occurrence for specific averaging periods.

Areas in violation of one or more of these standards are called *nonattainment areas*. If there are not enough air quality data to determine the status of attainment of a remote or sparsely populated area, the area is listed as *unclassified*. For regulatory purposes, unclassified areas are considered to be in attainment.

Section 176(c)(1) of the Clean Air Act requires Federal agencies to ensure that their actions conform to applicable implementation plans for achieving and maintaining National Ambient Air Quality Standards for criteria pollutants. In addition, this section of the Act assigns primary oversight responsibility to the agencies, not to the Environmental Protection Agency or the States. Specifically, for there to be conformity, a Federal action must not contribute to new violations of standards for ambient air quality, increase the frequency or severity of existing violations, or delay timely attainment of standards in the area of concern (for example, a State or a smaller air quality region). The Environmental Protection Agency general conformity regulations (40 CFR 93, Subpart B) contain guidance for determining if a proposed Federal action would cause emissions to be above certain levels in locations designated as nonattainment or maintenance areas. In this case, a maintenance area is a region that was previously in nonattainment, but which has been redesignated to an attainment area with a requirement to develop a maintenance plan.

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Table 3-5. National and Nevada ambient air quality standards.[a]

Pollutant	Primary and Secondary NAAQS,[b] except as noted: Period	Concentration	Highest measured Yucca Mountain concentration[c]	Nevada standards[d]
Sulfur dioxide	Annual[e]	0.03 part per million	0.002	Same
	24-hour[f]	0.14 part per million	0.002	
Sulfur dioxide (secondary)	3-hour[f]	0.5 part per million	0.002	
PM_{10}[g]	Annual[h]	50 micrograms per cubic meter	12	Same
	24-hour[i]	150 micrograms per cubic meter	67	
$PM_{2.5}$[j]	Annual[h]	15 micrograms per cubic meter	N/A[k]	None
	24-hour[l]	65 micrograms per cubic meter	N/A	
Carbon monoxide	8-hour[f]	9 parts per million	0.2	Same[m]
	1-hour[f]	35 parts per million	0.2	Same
Nitrogen dioxide	Annual[e]	0.053 part per million	0.002	Same
Ozone	1-hour[n]	0.12 part per million	0.1	Same
	8-hour[o]	0.08 part per million	N/A	None

a. Sources: 40 CFR 50.4 through 50.11; Nevada Administrative Code 445B.391.
b. NAAQS = National Ambient Air Quality Standard.
c. Units correspond to the units listed in the concentration column.
d. Nevada Administrative Code 445B.391.
e. Average not to be exceeded in the period shown.
f. Average not to be exceeded more than once in a calendar year.
g. PM_{10} = particulate matter with a diameter less than 10 micrometers (0.0004 inch). Until the revised State Implementation Plan is approved, 40 CFR 50.6 applies; then 40 CFR 50.7 would apply.
h. Expected annual arithmetic mean should be less than value shown.
i. Number of days per calendar year exceeding this value should be less than 1. Under 40 CFR 50.7, 99th-percentile value should be less than value shown.
j. $PM_{2.5}$ = particulate matter with a diameter less than 2.5 micrometers (0.0001 inch). Standard has not been implemented.
k. N/A = not available; no monitoring data has been collected since the new standard was implemented.
l. 98th-percentile value should be less than value shown.
m. The Nevada ambient air quality standard for carbon monoxide is 9 parts per million at less than 1,500 meters (4,900 feet) above mean sea level and 6 parts per million at or above 1,500 meters; Nevada Administrative Code 445B.31.
n. This standard was replaced in 1998 by 40 CFR 50.10 for all air quality regions of interest.
o. Standard promulgated in 1997, but not yet implemented due to court challenges. Three-year average of the fourth-highest monitored daily maximum 8-hour average concentration.

The quality of the air at the site of the proposed repository and the surrounding parts of the Nevada Test Site, Nellis Air Force Range (including southwestern Lincoln County), southwestern Esmeralda County, and southern Nye County is unclassified because there are limited air quality data (40 CFR 81.329). Data collected at the site indicate the air quality is within applicable standards. Portions of Clark County in the air quality region of influence are in attainment with the National Ambient Air Quality Standards. Inyo County, California, is in attainment with national and California ambient air quality standards for carbon monoxide, nitrogen dioxide, and sulfur dioxide. It is in attainment with the national *PM_{10} standard*, but in nonattainment with the more restrictive California standard (DIRS 103161-CEPA 1998, pp. H6 to H35). Outside the repository air quality region of influence, most of Nevada is unclassified and therefore in attainment. There are Nevada exceptions; Reno and Las Vegas are both in nonattainment for carbon monoxide and PM_{10} and the Lake Tahoe basin is in nonattainment for carbon monoxide. In addition, the Reno area is in nonattainment for ozone. Section 3.2.2 contains additional air quality information.

Air quality in attainment areas is controlled under the Prevention of Significant Deterioration program of the Clean Air Act, with the goal of preventing significant deterioration of existing air quality. Under the Prevention of Significant Deterioration provisions, Congress established a land classification scheme for areas of the country with air quality better than the National Ambient Air Quality Standards. Class I allows very little deterioration of air quality; Class II allows moderate deterioration; and Class III allows more deterioration; but in all cases the pollution concentrations shall not violate any of the National

Ambient Air Quality Standards. Congress designated certain areas as mandatory Class I, which precludes redesignation to a less restrictive class, to acknowledge the value of maintaining these areas in relatively pristine condition. Congress also protected other nationally important lands by originally designating them as Class II and restricting redesignation to Class I only.

All other areas were initially classified as Class II, and can be redesignated as either Class I or Class III. In the region of influence, all areas are designated as Class II. There are no Class I areas, although one area, the Death Valley National Park, is a national monument and a protected Class II area that could be redesignated as Class I (DIRS 148117-EPA 1998, all; DIRS 148119-EPA 1997, all). It is about 35 kilometers (22 miles) southwest of Yucca Mountain.

The construction and operation of a facility in an attainment area could be subject to the requirements of the Prevention of Significant Deterioration program if the facility received a classification as a major source of air pollutants. At present, the proposed repository site and the Nevada Test Site have no sources subject to those requirements (DIRS 101811-DOE 1996, p. 4-146).

As part of Yucca Mountain site characterization, DOE obtained an air quality operating permit from the State of Nevada (DIRS 104920-Del Porto 1996, all). The permit places specific operating conditions on various systems that DOE uses during site characterization activities. These conditions include limiting the emission of criteria pollutants, defining the number of hours a day and a year a system is allowed to operate, and determining the testing, monitoring, and recordkeeping required for the system.

In 1997, the Environmental Protection Agency issued new National Ambient Air Quality Standards for ozone and particulate matter. The new standard for particulate matter (40 CFR 50.7) includes fine particles in the respirable range with diameters smaller than 2.5 micrometers (see Table 3-5). The implementation of this new standard applies to all areas, but initial monitoring will focus on urban areas because (1) this pollutant comes primarily from combustion (auto exhaust, etc.) rather than *fugitive dust* sources (windblown dust, etc.) and (2) the first priority for monitoring programs is the assessment of densely populated areas. The new (1997) standard for ozone included revoking the 1-hour ozone standard for all counties in the United States with no current measured violations, including all of Nevada and the region around Yucca Mountain, and replacing it with a new 8-hour ozone standard. The new particulate and ozone standards were challenged in court and subsequently overturned by a Federal appeals court (DIRS 148090-American Trucking Associations v. U.S. Environmental Protection Agency 1999, all). As a result, the Environmental Protection Agency reinstated the 1-hour ozone standard in July 2000. However, early in 2001 the U.S. Supreme Court upheld the ability of the Environmental Protection Agency to set national air quality standards (DIRS 156704-Whitman v. American Trucking Associations 2001, all). Following its ruling, the Supreme Court remanded the case back to the appeals court to resolve all outstanding issues in light of its opinion. Implementation of the standards is delayed pending resolution of implementation details and some additional legal issues.

In 1989, DOE began monitoring particulate matter at the site of the proposed repository as part of site characterization activities and later as part of the Nevada Air Quality operating permit requirements. Concentration levels of inhalable particles smaller than 10 micrometers in diameter have been well below applicable National Ambient Air Quality Standards, with annual average concentrations 20 to 25 percent of the standard (see Table 3-5).

From October 1991 through September 1995, DOE monitored the site of the proposed repository for gaseous criteria pollutants (carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide) as part of site characterization. The concentration levels of each pollutant were well below the applicable National Ambient Air Quality Standards (see Table 3-5). In fact, concentrations of carbon monoxide and sulfur dioxide were not detectable during the entire monitoring period. Nitrogen dioxide was detected occasionally at concentrations of a few parts per billion (around 0.002 part per million) by volume, probably from nearby vehicle exhausts, about 4 percent of the applicable annual average standard (see Table 3-5). Ozone was the only criteria pollutant routinely detected; the maximum hourly concentrations were 0.081 to 0.096 part per million, which is 67 to 80 percent of the 1-hour regulatory standard. The source of the ozone has not been determined, but could be urban areas in southern California.

3.1.2.2 Climate

The Yucca Mountain region has a relatively arid climate, with annual precipitation totals ranging between approximately 10 and 25 centimeters (4 and 10 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29). Precipitation at a given location depends on nearby topographic features. The winter season is mild, with some periods of below freezing temperatures. Occasional periods of persistent rain have produced more than 5 centimeters (2 inches) of rainfall in daily periods. The summer season is typically hot and dry, with occasional periods of monsoon thunderstorms producing locally large amounts of rain. Storms can produce more than 2.5 centimeters (1 inch) of rain in a matter of hours.

Mean nighttime and daytime air temperatures typically range from 22°C to 34°C (72°F to 93°F) in the summer and from 2°C to 10.5°C (34°F to 51°F) in the winter (DIRS 100117-CRWMS M&O 1997, pp. A-1 to A-16). Temperature extremes range from -15°C to 45°C (5°F to 113°F). On average, the daily range in temperature change is about 10°C (18°F). Higher elevations are cooler, though the coldest areas can be in canyons and washes to which heavy cold air flows at night. Relative humidity levels range from about 10 percent on summer afternoons to about 50 percent on winter mornings and to near 100 percent during precipitation events.

In the valleys, airflow is channeled by local topography, particularly at night during stable conditions (DIRS 100117-CRWMS M&O 1997, p. 4-13 to 4-16). With the exception of the nearby confining terrain, which includes washes and small canyons on the east side of Yucca Mountain, local wind patterns have a strong daily cycle of daytime winds from the south and nighttime winds from the north. Confined areas also have daily cycles, but the wind directions are along terrain axes, typically upslope in the daytime and downslope at night. Wind direction can also vary with height. As shown in Figure 3-3, the winds at a height of 60 meters (200 feet) show a strong north-south flow up and down the valley. The winds at 10 meters (33 feet) show a strong southerly flow, but at night the wind pattern reflects more of the drainage flow downslope from Yucca Mountain. Hourly average wind speeds are usually greater than 1.8 meters a second (4 miles an hour), indicating few calm periods. Over the entire monitoring network, the average wind speed ranges from 2.5 to 4.4 meters a second (5.6 to 9.8 miles an hour); the fastest 1-minute wind speeds range from 19 to 33 meters a second (42 to 74 miles an hour); and the peak gusts range from 26 to 38 meters a second (59 to 86 miles an hour). The highest wind speeds typically occur on exposed ridges.

Severe weather can occur in the region, usually in the form of summer thunderstorms. These storms can generate an abundant amount of lightning, strong winds, and heavy and rapid precipitation. Tornadoes can occur, though they are not a substantial threat in the region; four have been recorded within 240 kilometers (150 miles) of the site of the proposed repository during the past 53 years, and one occurred in 1987 in the Amargosa Desert about 50 kilometers (30 miles) south of the site (DIRS 100117-CRWMS M&O 1997, p. 4-26).

Paleoclimatology. Climate studies and analyses pursued as part of the Yucca Mountain project have also included paleoclimatology, which is the study of ancient climates. These studies looked at time scales as large as hundreds of millennia. The primary assumption associated with paleoclimatology efforts is that climate is cyclical so that past climates provide insight into potential future climates (DIRS 151945-CRWMS M&O 2000, p. 6.4-2). The efforts have incorporated studies of the Earth's orbital and global circulation parameters and how those parameters have affected ancient climates in the Yucca Mountain region. Orbital parameters include theories that the shape of the Earth's orbit and the "wobble"

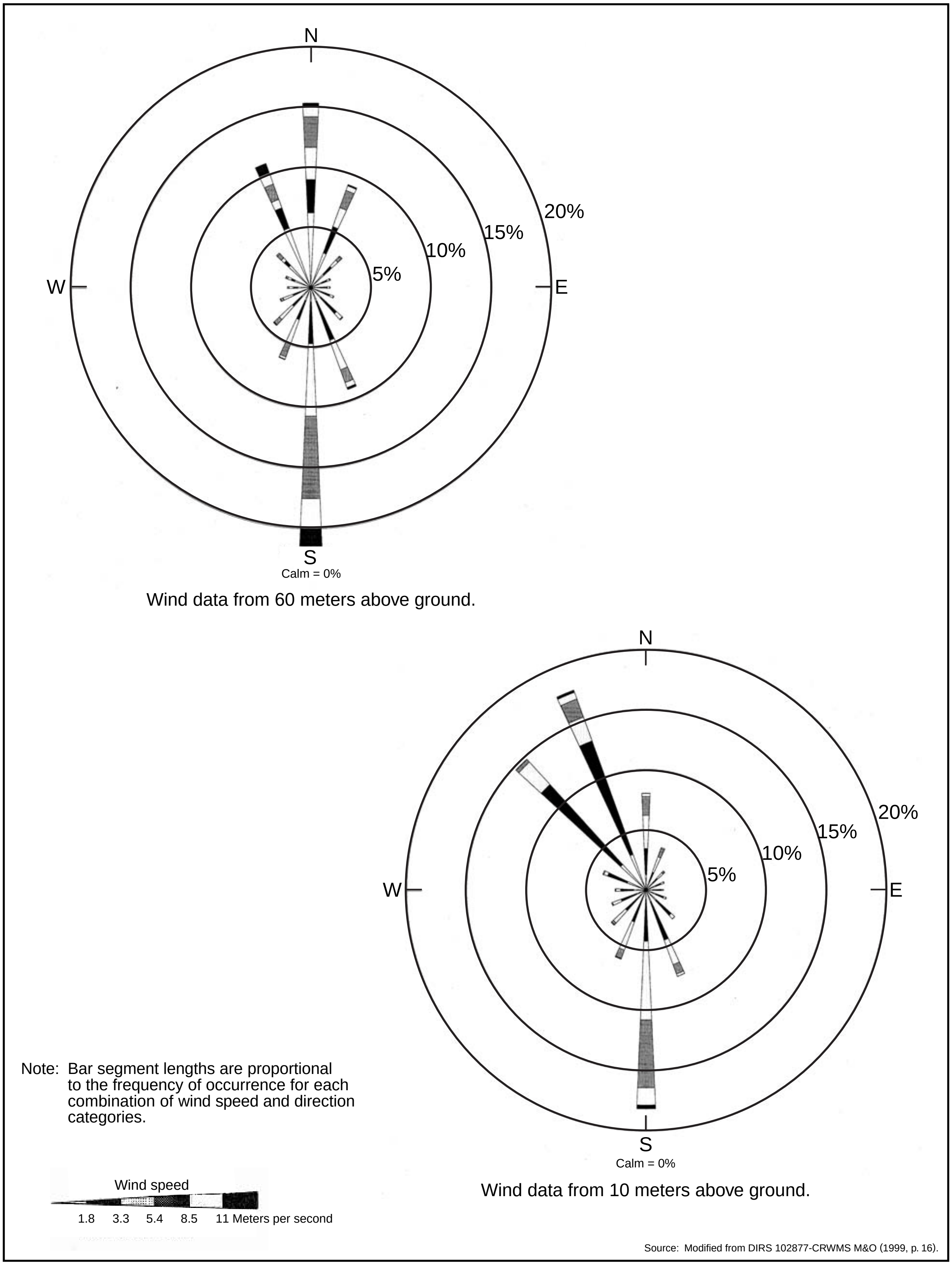

Figure 3-3. Wind rose plots for 10 and 60 meters (33 and 200 feet) above ground in the proposed repository facilities vicinity.

in its axial spin change in cycles that repeat over tens and hundreds of millennia (DIRS 151945-CRWMS M&O 2000, p. 6.3-4). Correlations have been made between these global position changes and long duration traces, or evidence, of paleoclimate conditions in the region. Two of the primary sources of this evidence are calcite deposited on the walls of rock fractures at Devils Hole in Nevada and lake deposits at the historic Owens Lake location in California. In these examples, analysis of residues left behind has provided insights into climate conditions as far back as 600,000 to 850,000 years ago (DIRS 151945-CRWMS M&O 2000, pp. 6.3-9 and 6.3-12).

Climate regimes believed to have existed in Yucca Mountain's past, and therefore that should occur in its future, have been grouped into the following categories: (1) a warm and dry, modern-like interglacial climate; (2) a warm and wet monsoon climate; (3) an intermediate glacial transition climate; and (4) glacial periods (DIRS 151945-CRWMS M&O 2000, pp. 6.4-11 and 6.4-17). The driest of these climate groupings is the modern-like interglacial climate and (as indicated by its name) represents the climate currently being experienced at Yucca Mountain. Characteristics of these climate regimes and postulated future durations are included as input parameters to the long-term performance assessment modeling performed for the site (DIRS 153246-CRWMS M&O 2000, pp. 3-38 to 3-42).

3.1.3 GEOLOGY

DOE has studied the existing physiographic setting (characteristic landforms), *stratigraphy* (rock strata), and geologic structure (structural features resulting from rock deformations) at Yucca Mountain and in the surrounding region. These studies have yielded detailed information about the surface and subsurface features in the region. This section describes the region of influence for geology, which includes the baseline conditions of the region's geology as well as the specific geology of Yucca Mountain. DOE investigated seismicity (*earthquake* activity) in the Yucca Mountain region; the investigations focused on understanding the Quaternary history of movement on faults in the region and the historic record of earthquake activity. The Department also investigated volcanoes in the Yucca Mountain region to assess the potential for volcanism to result in adverse effects to a repository. In addition, DOE considered the possibility that there might be minerals and energy resources at or near the site of the proposed repository.

3.1.3.1 Physiography (Characteristic Landforms)

Yucca Mountain is in the southern part of the *Great Basin* subprovince of the Basin and Range Physiographic Province (Figure 3-4), a region characterized by generally north-trending, linear mountain ranges separated by intervening valleys (basins) (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The Great Basin encompasses nearly all of Nevada plus parts of Utah, Idaho, Oregon, and California. Mountain ranges of the Great Basin, including Yucca Mountain, are mostly tilted, fault-bounded crustal blocks that are as much as 80 kilometers (50 miles) long and 8 to 24 kilometers (5 to 15 miles) wide. Ranges typically rise from 300 to 1,500 meters (1,000 to 4,900 feet) above the adjacent valley floors and occupy 40 to 50 percent of the total land area (DIRS 151945-CRWMS M&O 2000, pp. 4.4-1 and 4.4-2).

Valleys between the mountain ranges are filled with alluvial sediments (deposits of sand, mud, and other such materials formed by flowing water) from the adjacent ranges. Many valleys are called *closed basins* because they, like the Great Basin on a regional scale, lack a drainage outlet (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). Water and sediment from adjacent ranges become trapped and move to the lowest part of such valleys to form a *playa*, a flat area that is largely vegetation-free owing to high salinity, which results from evaporation of the water. Valleys with drainage outlets have intermittent stream channels that carry eroded sediment to lower drainage areas.

The present landscape, distinguished by the broad series of elongated mountain ranges alternating with parallel valleys, is the result of past episodes of faulting that elevated the ranges above the adjacent valleys. Section 3.1.3.2 addresses such faulting. Yucca Mountain is an irregularly shaped volcanic in its axial spin change in cycles that repeat over tens and hundreds of millennia (DIRS 151945-CRWMS M&O 2000, p. 6.3-4). Correlations have been made between these global position changes and long duration traces, or evidence, of paleoclimate conditions in the region. Two of the primary sources of this evidence are calcite deposited on the walls of rock fractures at Devils Hole in Nevada and lake deposits at the historic Owens Lake location in California. In these examples, analysis of residues left behind has provided insights into climate conditions as far back as 600,000 to 850,000 years ago (DIRS 151945-CRWMS M&O 2000, pp. 6.3-9 and 6.3-12).

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Almost without exception, west-facing slopes at Yucca Mountain are steep and east-facing slopes are gentle, which expresses the underlying geologic structure (see Section 3.1.3.2). Small valleys eroded in the mountain are narrow, V-shaped drainages that flatten and broaden near the mountain base. The crest of Yucca Mountain reaches elevations from 1,500 meters (4,900 feet) to 1,900 meters (6,300 feet) above sea level. The bottoms of the adjacent valleys are approximately 650 meters (2,100 feet) lower (DIRS 151945-CRWMS M&O 2000, p. 4.4-4).

Yucca Mountain is bordered on the north by Pinnacles Ridge and *Beatty Wash*, on the west by *Crater Flat*, on the south by the Amargosa Desert, and on the east by the Calico Hills and by *Jackass Flats*, which contains *Fortymile Wash* (Figure 3-6). Beatty Wash is one of the largest tributaries of the Amargosa River and drains the region north and west of Pinnacles Ridge, including the northern end of Yucca Mountain.

Crater Flat (Figure 3-6) is an oval-shaped valley between Yucca Mountain and *Bare Mountain*. It contains four prominent volcanic cinder cones and related lava flows that rise above the valley floor. Crater Flat drains to the Amargosa River through a gap in the southern end of the basin.

Jackass Flats is an oval-shaped valley east of Yucca Mountain bordered by Yucca, Shoshone, Skull, and Little Skull Mountains (Figure 3-6). It drains southward to the *Amargosa River*. *Fortymile Wash* is the most prominent drainage through Jackass Flats to the Amargosa River.

Site Stratigraphy and Lithology

The exposed stratigraphic section at Yucca Mountain is dominated by mid-Tertiary volcanic ash-flow and ash-fall deposits with minor lava flows and reworked materials. These deposits originated in the calderas shown in Figure 3-5. Regionally, the thick series of volcanic rocks that form Yucca Mountain overlies *Paleozoic* sedimentary rocks that are largely of marine origin. The volcanic rocks, in turn, are covered in many areas by a variety of late Tertiary and Quaternary surficial deposits (DIRS 151945-CRWMS M&O 2000, p. 4.5-1). The stratigraphic section is summarized in Table 3-6, which depicts rock assemblages according to the geologic age during which they were deposited. The stratigraphic sequence of the Yucca Mountain area consists, from oldest to youngest, of Pre-Cenozoic (that is, Paleozoic and Precambrian) sedimentary and metasedimentary (sedimentary rocks that have been altered by metamorphism), mid-Tertiary siliceous (rich in silica) volcanic rocks, Tertiary to Quaternary basalts, and late Tertiary to late Quaternary surficial deposits.

Only Tertiary and younger rocks are exposed at Yucca Mountain (DIRS 151945-CRWMS M&O 2000, p. 4.5-1). Parts of the older (Pre-Cenozoic) rock assemblages described in Table 3-6 are exposed at Bare Mountain, the Calico Hills, and the Striped Hills, to the east, northeast, and southeast of Yucca Mountain, respectively (see Figure 3-6) (DIRS 151945-CRWMS M&O 2000, Figures 4.2-3 to 4.2-6, pp. F4.2-3 to F4.2-6). Many of these older rocks are widespread in the Great Basin where their cumulative thickness is thousands of feet. Detailed information about their characteristics is lacking at Yucca Mountain because only one *borehole*, about 2 kilometers (1.2 miles) east of Yucca Mountain, has penetrated these rocks. Paleozoic carbonate rocks were penetrated in this borehole at a depth of about 1,250 meters (4,100 feet) (DIRS 102046-Carr et al. 1986, p. 5-5). Paleozoic carbonate rocks form important aquifers in southern Nevada (DIRS 101167-Winograd and Thordarson 1975, all).

Table 3-7 lists the principal mid-Tertiary volcanic stratigraphic units mapped at the surface, encountered in boreholes, and examined in the Exploratory Studies Facility that have been a major focus of site characterization investigations. The proposed repository and access to it would be entirely in the Paintbrush Group, so investigations have focused particularly on the formations in that stratigraphic unit. Detailed descriptions of the volcanic stratigraphic units are in the Yucca Mountain Project Stratigraphic Compendium (DIRS 101535-CRWMS M&O 1996, all). The following paragraphs provide a general

Table 3-6. Highly generalized stratigraphy summary for the Yucca Mountain region.[a]

Geologic age designation	Major rock types (lithologies)
Cenozoic Era	
Quaternary Period (< 1.6 Ma)[b]	Alluvium; basalt
Tertiary Period (< 65 - 1.6 Ma)	Silicic ash-flow tuffs; minor basalts. Predominantly volcanic rocks of the southwestern Nevada volcanic field (includes Topopah Spring Tuff, host rock for the potential repository). Table 3-7 lists major Tertiary volcanic formations at Yucca Mountain.
Mesozoic Era (240 - 65 Ma)	No rocks of this age found in Yucca Mountain region.
Paleozoic Era (570 - 240 Ma)	Three major lithologic groups (lithosomes) predominate: a lower (older) carbonate (limestone, dolomite) lithosome deposited during the Cambrian through Devonian Periods (see Figure 3-17), a middle fine-grained clastic lithosome (shale, sandstone) formed during the Mississippian Period, and an upper (younger) carbonate lithosome formed during the Pennsylvanian and Permian Periods.
Precambrian Era (> 570 Ma)	Quartzite, conglomerates, shale, limestone, and dolomite that overlie older igneous and metamorphic rocks that form the crystalline "basement."

a. Source: Adapted from DIRS 151945-CRWMS M&O (2000, pp. 4.2-3 to 4.2-20).
b. Ma = approximate years ago in millions.

summary based on the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, pp. 4.5-1 to 4.5-34).

The bulk of the volcanic sequence consists of tuffs. Volcanic rocks known as ash-flow tuffs (or *pyroclastic* flow deposits) form when a hot mixture of volcanic gas and ash violently erupts and flows.

As the ash settles, it is subjected to various degrees of compaction and fusion depending on temperature and pressure conditions. If the temperature is high enough, glass and pumice fragments are compressed and fused to produce welded tuff (a hard, brick-like rock with very little open pore space in the rock *matrix*). Nonwelded tuffs, compacted and consolidated at lower temperatures, are less dense and brittle and generally have greater porosity. Ash-fall tuffs are formed from ash that cooled before settling on the ground surface, and bedded tuffs are composed of ash that has been reworked by stream action. All of these are found in the volcanic assemblage at Yucca Mountain.

In general, characterization of the various volcanic units is based on changes in depositional features, the development of zones of welding and devitrification (crystallization of glassy material), and the development of alteration products in some rocks. Mineral and chemical composition and properties such as density and porosity also have been used in distinguishing some units. Most of the formations listed in Table 3-7 contain phenocrysts (mineral grains distinctly larger than the surrounding rock matrix) and lithic clasts (rock fragments), have some part that is at least partially welded, and typically have some part that has devitrified during cooling of the deposit. In addition, the vitric (glassy) parts of many formations have been partly altered to clay and *zeolite* minerals, and all the rocks have developed various amounts of fractures, some of which contain secondary mineral fillings.

Lithophysal cavities are prominent features in some units, notably in the Tiva Canyon and Topopah Spring Tuffs, where they range from 1 to 50 centimeters (0.4 to 20 inches) in diameter and are a basis for the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

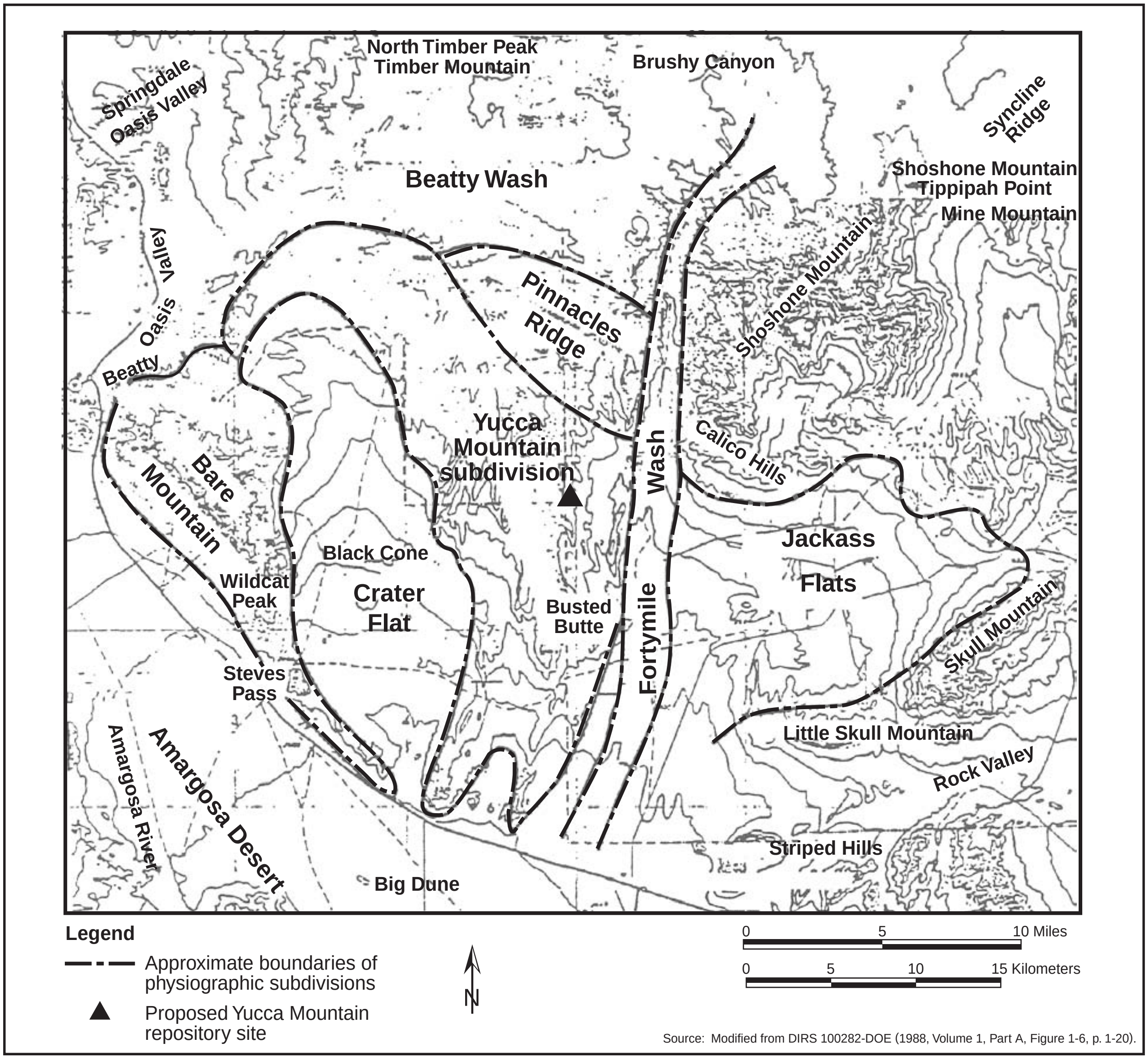


Figure 3-6. Physiographic subdivisions in the Yucca Mountain vicinity.

Although welded tuffs dominate the volcanic sequence, bedded tuffs are present in the Paintbrush Group and in some older parts of the sequence (DIRS 151945-CRWMS M&O 2000, Figures 4.5-3 and 4.5-4, pp. F4.5-3 to F4.5-4). Joints and fractures are common in the welded tuffs, producing much greater bulk permeabilities than those of the nonwelded and bedded tuffs (DIRS 151945-CRWMS M&O 2000, p. 4.10-6). This is an important distinction with regard to investigation of hydrologic conditions.

Some parts of the volcanic formations contain secondary mineral products created by alteration of the original materials after their original deposition and consolidation. Some alteration has resulted from reactions with groundwater, and the types of new mineral substances found can differ based on occurrence below or above the water table. Alteration products such as clay minerals and zeolites occur in several parts of the volcanic sequence; in some places, in-filling with zeolites has reduced the porosity and thus affected hydrologic properties. In most of the formations, contacts between vitric and devitrified layers are commonly marked by an interval containing clay or zeolite alteration minerals. A notable example is the interval, as much as several meters thick, where glassy rock at the base of the Topopah

Table 3-7. Tertiary volcanic rock sequence at Yucca Mountain.[a]

Name	Age (millions of years)[b]	Thickness (meters)[c]	Characteristics
Timber Mountain Group			
• Ammonia Tanks Tuff	11.5	Up to 215	Welded to nonwelded rhyolite tuff; exposed in southern Crater Flat.
• Rainier Mesa Tuff	11.6	< 30 - 240	Nonwelded to moderately welded vitric to devitrified tuff exposed locally along downthrown sides of large normal faults.
Post-Tiva Canyon, pre-Rainier Mesa Tuffs	12.5	0 - 61	Pyroclastic flows and fallout tephra deposits in subsurface along east flank of Yucca Mountain.
Paintbrush Group			Four formations (below) interlayered locally with lava flows and reworked volcanic deposits.
• Tiva Canyon Tuff	12.7	< 50 - 175	Crystal-rich to crystal-poor densely welded rhyolite tuff that forms most rock at surface of Yucca Mountain.
• Yucca Mountain Tuff	--[d]	0 - 45	Mostly nonwelded tuff but is partially to densely welded where it thickens to north and west.
• Pah Canyon Tuff	--	0 - 70	Northward-thickening nonwelded to moderately welded tuff with pumice fragments.
• Topopah Spring Tuff	12.8	Up to 380	Rhyolite tuff divided into upper crystal-rich member and lower crystal-poor member. Each member contains variations in lithophysal content, zones of crystallization, and fracture density. Glassy unit (vitrophyre) present at the base. Proposed host for repository.
Calico Hills Formation	12.9	15 - 460	Northward-thickening series of pyroclastic flows, fallout deposits, lavas, and basal sandstone; abundant zeolites except where entire formation is vitric in southwest part of central block of Yucca Mountain.
Crater Flat Group			Pyroclastic flows and interbedded tuffs of rhyolitic composition distinguished by abundance of quartz and biotite.
• Prow Pass Tuff	13.1	60 - 228	Sequence of variably welded pyroclastic deposits.
• Bullfrog Tuff	13.3	76 - 275	Partially welded, zeolitic upper and lower parts separated by a central densely welded tuff.
• Tram Tuff	13.5	60 - 396	Lower lithic-rich unit overlain by upper lithic-poor unit.
Lithic Ridge Tuff	13.9	185 - 304	Southward thickening wedge of welded and nonwelded pyroclastic flows and interbedded tuff extensively altered to clays and zeolites.
Pre-Lithic Ridge	+14.0	45 - 350	Mostly altered pyroclastic flows, lavas, and bedded tuff of rhyolitic composition.

a. Modified from DIRS 151945-CRWMS M&O (2000, pp. 4.5-19 to 4.5-33).
b. Source: DIRS 151945-CRWMS M&O (2000, Table 4.2-3, p. T4.2-3).
c. To convert meters to feet, multiply by 3.208.
d. -- = no absolute dates.

the further subdivision of these formations. Lithophysal cavities are voids resulting from vapors trapped in densely welded parts of the formations. Lithophysal zones contain fewer fractures compared to nonlithophysal zones.

Spring Tuff (the basal *vitrophyre*) is in contact with the overlying nonlithophysal zone; this interval of alteration occurs in most boreholes in the vicinity of the proposed site (DIRS 151945-CRWMS M&O 2000, p. 4.5-11). Subtle differences in geochemical conditions are believed to have given rise locally over short distances to some unusual zeolites. One in particular is the fibrous zeolite *erionite*, which is a potential human health hazard (see Section 3.1.8.3). Data from rock samples show that in the potential repository horizon erionite, if it occurs, is either in the altered zone immediately above the Topopah Spring lower vitrophyre or in the moderately welded zone underlying this vitrophyre. It has also been identified in the lower Tiva Canyon Tuff (DIRS 101779-DOE 1998, Volume 1, p. 2-25).

Figure 3-7 is a geologic map that shows the surficial distribution of Tertiary volcanic units and younger surficial deposits in the vicinity of the proposed site. Figure 3-8 is a vertical cross-section through the southern part of this area that shows the subsurface expression of the mapped units, including structural aspects (east-dipping rock units and predominantly west-dipping normal faults). Examples of Tertiary units include the lava flows that cap Skull and Little Skull Mountains at the south and southeast margins of Jackass Flats, a *basalt* ridge that forms the southern boundary of Crater Flat, and a basaltic dike dated at 10 million years (DIRS 151945-CRWMS M&O 2000, p. 4.5-33) that intrudes in the northern part of the Solitario Canyon fault, which bounds the west flank of Yucca Mountain. Volcanic rocks younger than the Tertiary units occur locally at and in the Yucca Mountain vicinity but are of limited extent (Figure 3-5). They represent low-volume eruptions typically consisting of a single main cone surrounded by a small field of basalt flows. A north-trending series of cinder cones and lava flows on the southeast side of Crater Flat has been dated at 3.7 million years, and in the center of Crater Flat a series of four northeast-trending cinder cones (Qbo in Figure 3-5) has been dated at about 1 million years. The youngest basaltic center is the Lathrop Wells center, which is a single cone estimated to be 80,000 years old, with several different age dating methods putting the age between 70,000 and 90,000 years (DIRS 151945-CRWMS M&O 2000, p. 12.2-5). Some authors, however, cite evidence for *polycyclic volcanism*, suggesting a significant time interval between the emplacement of the Lathrop Wells *scoria* deposits.

The youngest stratigraphic units at Yucca Mountain are the predominantly unconsolidated surficial deposits of late Tertiary and Quaternary age. They are shown in Figure 3-7 as *alluvium* (material such as sand, silt, clay, pebbles, cobbles, or even boulders deposited on land by water) and *colluvium* (loose earth material that has accumulated at the base of a hill through the action of gravity) but have been classified in more detail as stream (alluvial) deposits, hillslope (colluvial) deposits, spring deposits, and windblown (eolian) deposits (DIRS 151945-CRWMS M&O 2000, pp. 4.4-10 to 4.4-21). Most Quaternary units exposed at the surface were deposited during the last 100,000 years (DIRS 101779-DOE 1998, Volume 1, p. 2-26). The bulk of these consist of alluvium deposited by intermittent streams that transported rock debris from hillslopes to adjacent washes and valleys.

Selection of Repository Host Rock

Selection of the potential repository emplacement area was based on several considerations, which include (1) depth below the ground surface sufficient to protect *nuclear waste* from exposure to the environment, (2) extent and characteristics of the host rock, (3) location away from major faults that could adversely affect the stability of underground openings or act as pathways for water flow that could eventually lead to radionuclide release, and (4) location of the water table in relation to the proposed repository (DIRS 104956-CRWMS M&O 1993, pp. 5-99 to 5-101).

DOE selected the middle to lower portion of the Topopah Spring Tuff as the potential repository horizon. The rock is strongly welded with variable *fracture* density and void space; experience gained from the excavation of the Exploratory Studies Facility shows the capability to construct stable openings in this rock. Thermal and mechanical properties of this section of rock should enable it to accommodate the range of temperatures anticipated (thermal properties will not be affected greatly by construction and operation, as compared to postemplacement), and the identified repository volume is between major faults. Finally, the selected repository horizon is well above the present groundwater table. Based on geologic evidence the water table under Yucca Mountain has not been more than about 120 meters (390 feet) higher than its present level in the past several hundred thousand years; at such levels the water table would still be about 40 to 280 meters (130 to 920 feet) below the selected repository horizon (DIRS 151945-CRWMS M&O 2000, p. 9.4-1). Section 3.1.4 discusses the water table level further.

Potential for Volcanism at the Yucca Mountain Site

DOE has performed extensive investigations to determine the ages and nature of the volcanic episodes that produced the rocks described above (DIRS 151945-CRWMS M&O 2000, Chapters 4, 5, and 12). The rocks that form the southwestern Nevada volcanic field, characterized by large-volume silicic ash flows (including the host rock for the proposed repository), were erupted during a period of intense tectonic activity associated with active geologic faulting (DIRS 100075-Sawyer et al. 1994, all). The volcanism that produced these ash flows is complete (has not occurred in the region for more than 7.5 million years) and, based on the geology of similar volcanic systems in the Great Basin, no additional large-volume silicic activity is likely (DIRS 101779-DOE 1998, Volume 1, p. 2-85).

Basaltic volcanism in the Yucca Mountain region began about 11 million years ago as silicic eruptions waned and continued as recently as about 80,000 years ago. Basaltic volcanic events were much smaller in magnitude and less explosive than the events that produced the ash flows mentioned above. Typical products are the small volcanoes or cinder cones and associated lava flows in Crater Flat (about 1 million years old) and the Lathrop Wells volcano (possibly as young as 80,000 years) (DIRS 151945-CRWMS M&O 2000, p. 4.2-19). The potential for future volcanic activity in the Yucca Mountain region would be associated with basaltic volcanism rather than silicic activity.

Differing views on the likelihood of volcanism near Yucca Mountain result from uncertainties in the hazard assessment. To address these uncertainties, DOE has performed analyses, conducted extensive volcanic hazard assessments, considered alternative interpretations of the geologic data, and consulted with recognized experts, representing other Federal agencies (for example, the U.S. Geological Survey), national laboratories, and universities (for example, the University of Nevada and Stanford University). In 1995 and 1996, a panel of 10 scientists from these agencies and institutions and with expertise in volcanism reviewed the extensive information on volcanic activity in the Yucca Mountain vicinity and assessed the likelihood that future volcanic activity could occur at or in the vicinity of the repository (DIRS 151945-CRWMS M&O 2000, p. 12.2-21).

The probability of basaltic lava intruding into the repository is expressed as the annual probability that a volcanic event would disrupt (intersect) a repository, given that a volcanic event would occur during the period of concern. The expert panel assessed uncertainties associated with the data and models used to evaluate the potential for disruption of the potential Yucca Mountain Repository by a volcanic intrusion (dike) (DIRS 100116-CRWMS M&O 1996, all). The panel estimated the probability of a dike disrupting the repository during the first 10,000 years after closure to be 1 chance in 7,000. The estimate was recalculated to account for the current footprint of the proposed repository. The revised estimate increases to about 1 chance in 6,300 (with 5th and 95th percentiles of 1 chance in 130,000 and 1 chance in 2000, respectively, of a volcanic dike disrupting the repository) during the first 10,000 years with the current repository layout, considering both primary and contingency blocks (DIRS 151945-CRWMS M&O 2000, pp. 12.2-27 and 12.2-28 and Table 12.2-8).

3.1.3.2 Geologic Structure

Geologic structures (folds, faults, etc.) are features that result from deformation of rocks after their original formation. The present-day geologic structure of the Great Basin, including the Yucca Mountain region, is the cumulative product of multiple episodes of deformation caused by both compression and extension (stretching) of the Earth's crust.

Major east-west crustal compression occurred periodically in the Great Basin between about 350 million and 65 million years ago (DIRS 151945-CRWMS M&O 2000, pp. 4.2-21 and 4.2-27). This compression moved large sheets of older rock great distances upward and eastward over younger rocks (for example, thrust faults) to produce mountains. During the last 20 million years, crustal extension has resulted in the pattern of elongated mountain ranges and intervening basins (DIRS 151945-CRWMS M&O 2000, pp. 4.2-27 and 4.2-28). Crustal extension has resulted in vertical, lateral, and oblique movements (Figure 3-9). By about 11.5 million years ago the present mountains and valleys were well developed (DIRS 104181-Scott and Bonk 1984, all; DIRS 101557-Day et al. 1998, all).

Figure 3-7 shows the bedrock geology at the Yucca Mountain site and Figure 3-8 shows geologic structure. Figure 3-10 shows the surface traces of faults and their characteristic northerly alignment.

The crustal extension during the last 20 million years fractured the crust along the generally north-trending normal faults. Some of the crustal blocks were downdropped and tilted by movement along their bounding faults (called block-bounding faults). The estimated total displacement along the major north-trending block-bounding faults during the last 12 million years ranges from less than 100 meters (330 feet) to greater than 500 meters (1,600 feet) (DIRS 151945-CRWMS M&O 2000, pp. 12.3-38 to 12.3-58).

Measurements of Quaternary (1.6 million years to present) displacement reported on these faults range from 0 to 6 meters (0 to 20 feet), with most displacement in the 1-to-2.5-meter (3.3-to-8.2-foot) range (DIRS 101929-Simonds et al. 1995, Table 2). Displacements along faults are characterized in terms of the amount of movement per seismic event. For the set of faults of primary significance to the Yucca Mountain site, these values range from 0 to 1.7 meters (0 to 5.6 feet) per event (Table 3-8).

Table 3-8 lists the characteristics of the faults that are important to an understanding of seismic hazards to the potential repository. The Solitario Canyon fault along the west side of Yucca Mountain and the Bow Ridge Fault along the east side are the major block-bounding faults that bracket the area under consideration for the proposed repository. The proposed repository has been configured so that there would be no block-bounding faults in the emplacement zone.

Between the major north-trending, block-bounding faults there are *intrablock* or *subsidiary faults*. One intrablock fault, called the Ghost Dance fault, is in the area of the proposed repository. The Ghost Dance fault has a near-vertical dip from the surface to the depth of the repository (DIRS 151945-CRWMS M&O 2000, p. 4.6-22). This fault crosses the Exploratory Studies Facility tunnel. There is no evidence of Quaternary movement along the Ghost Dance fault (Table 3-8). Within the repository block, there are many subsidiary northwest-trending faults with smaller displacements than the block-bounding faults (DIRS 104181-Scott and Bonk 1984, all). There is no clear evidence that displacements have occurred along these subsidiary faults during the last 1.6 million years (DIRS 101929-Simonds et al. 1995, all). One short northwest-trending subsidiary fault, called the Sundance fault, transects the potential repository area (Figure 3-10).

The faults described above are associated with well-defined fractures in the rock structure. In addition to these fault fractures where there is a displacement of the sides in relation to each other, there are also fractures along which no appreciable movement has occurred. These are called *joints*. In the Paintbrush

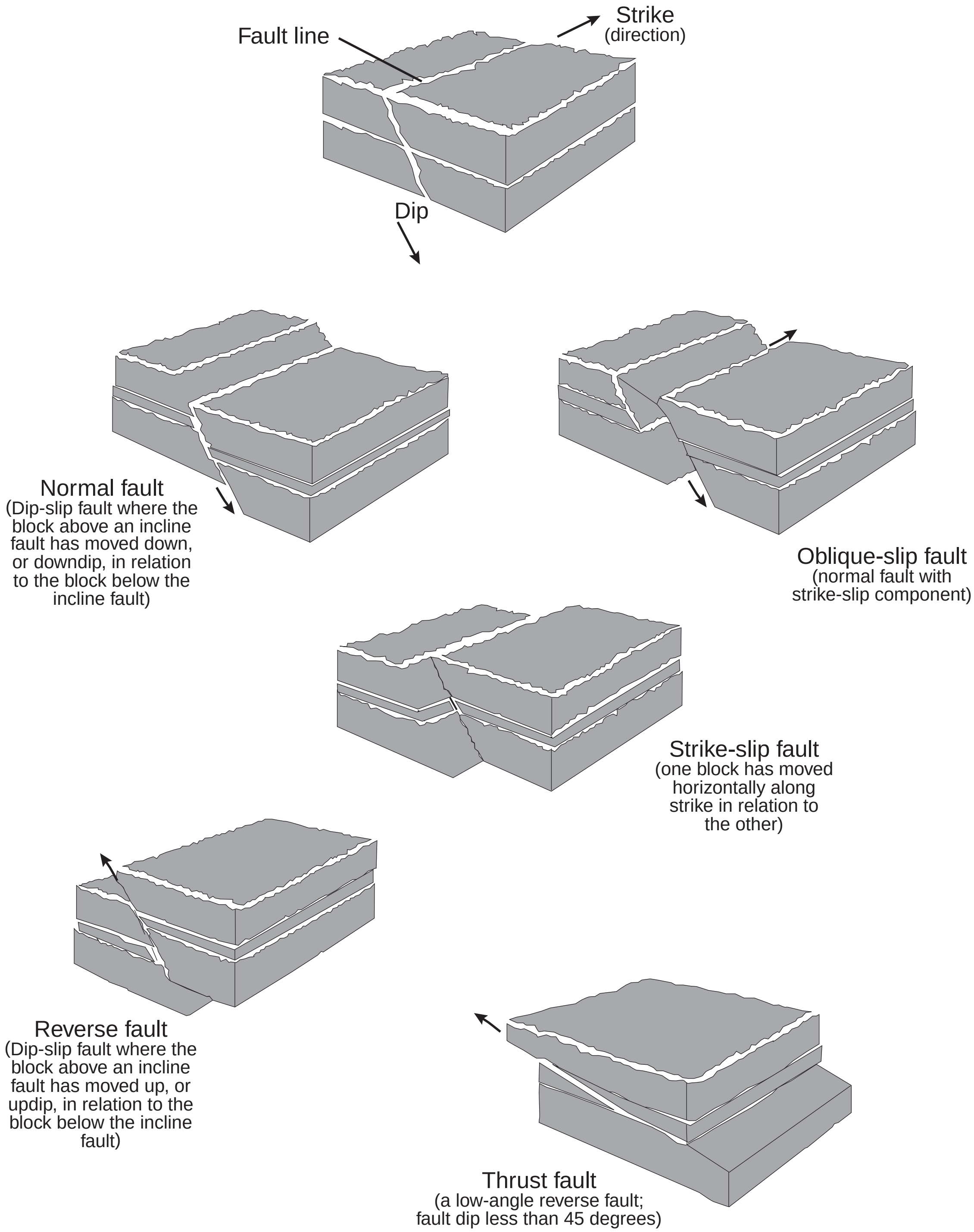
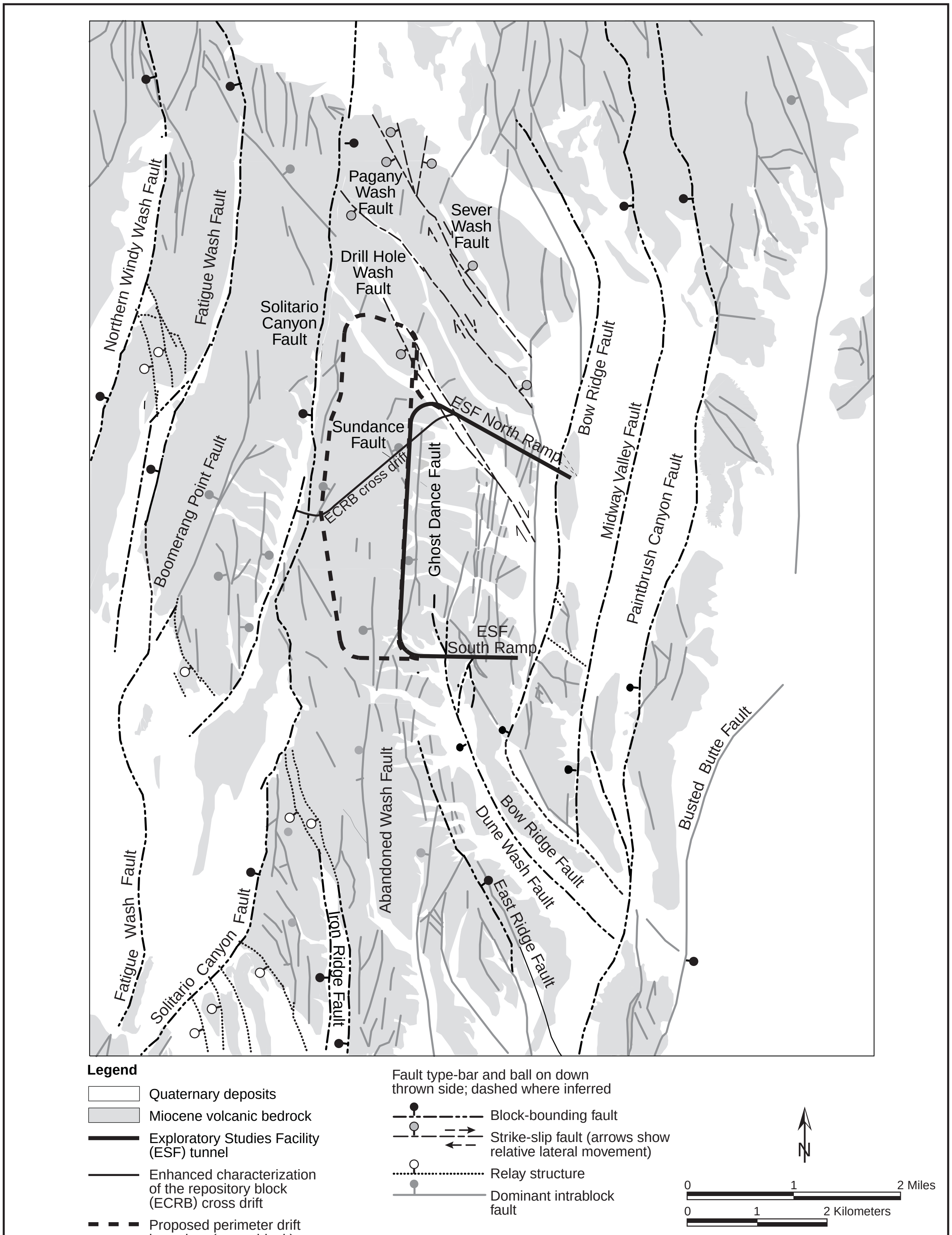


Figure 3-9. Types of geologic faults.



Source: Modified from DIRS 151945-CRWMS M&O (2000, Figure 4.6-2, p. F4.6-2).

Figure 3-10. Mapped faults at Yucca Mountain and in the Yucca Mountain vicinity.

Table 3-8. Characteristics of major faults at Yucca Mountain.[a]

Fault	Surface features	Evidence of Quaternary displacement	Displacement per event[b] (meters)[c]	Total displacement; type of movement	Fault length (kilometers)[b] and dip
Crater Flat fault zone (north and south fault zones)	North zone has 2 faults 300-600 meters apart, bedrock faults and scarps, subtle scarps and lineaments in alluvium, bedrock/alluvium fault contacts.	3 of 3 trenches show multiple events; lineaments in alluvium, subtle scarps and fractures in alluvium.	0 - 0.5, north, 0.1-0.2, south	Total displacement unknown; oblique, left-lateral, west side down.	1 - 20 individual, 5 - 40 combined 70° west (north); 82° to 89° west (south)
Windy Wash fault[e]	Fault-line scarps in alluvium; bedrock/alluvium fault contacts; merges with Fatigue Wash fault.	3 of 3 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium	0.7	Less than 500 meters; mostly dip-slip, west side down	3 - 35; 77° west to vertical
Fatigue Wash fault[e]	Bedrock and alluvial scarps; fault-line scarps, lineaments in alluvium; merges with Windy Wash fault.	2 of 2 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.3 - 1.3	75 meters; oblique left-lateral, west side down.	10 - 17; 73° west
Solitario Canyon fault[e]	Prominent fault-line scarp; discontinuous fault traces; subtle scarps in alluvium; southeastern splay is the Iron Ridge Fault.	6 of 11 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0 - 1.3	Increases southward from 0 to >500 meters; mostly normal with minor oblique left-lateral, down on east at north end, down on west at south end.	12.5 - 22; 72° west
Stagecoach Road fault	Prominent scarp and traceable faults in alluvium, merges with Solitario Canyon fault and (or) Paintbrush Canyon fault.	2 of 3 trenches show multiple events; fractures and scarps in alluvium; basalt ash in faulted alluvium.	0.4 - 0.7	400 to 600 meters; normal dip-slip to left oblique, west side down.	4 - 5 73° west
Ghost Dance fault zone[f]	Bedrock fault in zone of subparallel minor faults and breccia zones.	None	None	Increases southward from up to 5 meters at north end and 12-15 meters in central portion; dip-slip, west side down.	3 - 9; > 65° west
Bow Ridge fault[e]	Fault-line scarp along bedrock/alluvium contact; subtle lineaments; may merge along strike with Paintbrush Canyon fault.	3 of 7 trenches show multiple ruptures; basalt ash in fault plane; fractures and scarps in alluvium.	0.1 - 0.4	125 meters; oblique left-lateral, west side down.	6-10; 65° to 85° west
Midway Valley fault[e]	None, fault located on basis of geophysical evidence.	None	None in late Quaternary	40 - 60 meters; dip-slip, west side down.	1 - 5; west[g]
Paintbrush Canyon fault[e]	Bedrock and alluvial faults, scarps, and lineaments; possibly merges along strike with Stagecoach Road fault.	6 of 14 sites (10 trenches in Midway Valley and 4 exposures at Busted Butte) show multiple ruptures; basalt ash in fault plane; fractures in alluvium.	0.06 - 1.7	250 - 500 meters; dip-slip and oblique left-lateral, west side down.	10 - 26; 70° west
Northwest-trending faults[h] (not major faults)	Bedrock faults with local fault line scarps; most located by drilling and geophysical surveys.	None, with the exception of one trench across Pagany Wash fault showing absence of Quaternary displacement.	None (see column to left).	Undetermined; right-lateral to oblique right-lateral. (Except Dune Wash: 50-100 meters; normal, west side down.)	Undetermined; dip varies

a. Source: Modified from DIRS 106342-Menges and Whitney (1996, Table 4.2.1) with data from DIRS 151945-CRWMS M&O (2000, pp. 12.3-38 to 12.3-58; Tables 12.3-8a, -8b, and -9; pp. T12.3-7 to T12.3-19).
b. Preferred estimate of surface displacement associated with a prehistoric earthquake.
c. To convert meters to feet, multiply by 3.2808.
d. To convert kilometers to miles, multiply by 0.62137.
e. Block bounding fault.
f. Intrabock fault.
g. The dip and direction of this fault are uncertain.
h. Subsidiary northwest tending faults, includes the Pagany Wash, Sever Wash, Drill Hole Wash, and Dune Wash faults.

Group (Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring tuffs), joints are subdivided into three groups based on their generating mechanism and time of occurrence: early cooling joints, later tectonic joints, and joints due to erosional unloading (DIRS 151945-CRWMS M&O 2000, pp. 4.7-5 to 4.7-7). Each type of joint exhibits different characteristics with respect to its length, orientation, and connectivity. The cooling and tectonic joints have similar orientations (generally running north-south), but cooling joints include irregularly spaced horizontal joints as well. Joints due to erosional unloading are variably oriented but tend predominantly east to west, cross-wise to the cooling and tectonic joints. Tectonic joints occur throughout the Paintbrush Group and cooling joints are identified in each of the welded units. In general, the highest joint frequencies and connectivities occur in the units of the Tiva Canyon and Topopah Spring tuffs and the lowest occur in the nonwelded Yucca Mountain and Pah Canyon tuffs. Most joints, particularly cooling joints, are confined to specific rock units and do not cross unit boundaries. They do not generally form through-going features like faults. Geologic, geoengineering, and hydrologic aspects of fractures are discussed in detail in the Yucca Mountain Site Description (DIRS 151945-CRWMS M&O 2000, pp. 4.6-17 to 4.6-19, 4.7-5 to 4.7-7, 4.7-36 to 4.7-40, and 8.9-1 to 8.9-15).

DOE identified and described alternative tectonic models to explain the current geologic structure resulting from past tectonic processes and deformation events that have affected the Yucca Mountain site. These models are described in the *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.3), and were considered by the experts in the Probabilistic Seismic Hazard Analysis (DIRS 100354-USGS 1998, all) discussed below. Computer models provide a means of integrating data on volcanism, deposition, and fault movement, and include a representation of the existing geologic structures and the processes that operate at depth. Tectonic models provide a basis for evaluating the processes and events that could occur in the future and potentially affect the performance of a repository. The DOE hazard assessments used models that are supported by data.

3.1.3.3 Modern Seismic Activity

DOE has monitored seismic activity at the Nevada Test Site since 1978. The epicenters of many earthquakes that the Southern Great Basin Seismic Network has located within 20 kilometers (12 miles) of Yucca Mountain do not correlate with mapped surface traces of Quaternary faults (DIRS 151945-CRWMS M&O 2000, pp. 12.3-17 and 12.3-18). This lack of correlation is a common feature of earthquakes, particularly those of smaller magnitude, in the Great Basin and elsewhere. Earthquakes in the Yucca Mountain region have focal depths (the point of origin of an earthquake below the ground surface) ranging from near-surface to about 5 to 12 kilometers (3 to 7 miles) (DIRS 151945-CRWMS M&O 2000, p. 12.3-18). The earthquake focal mechanisms are *strike-slip* to normal *oblique-slip* along moderately to steeply dipping fault surfaces. These focal mechanisms indicate the nature of the fault planes on which the earthquakes occur, as shown in Figure 3-9.

The largest recorded historic earthquake within 50 kilometers (30 miles) of Yucca Mountain was the Little Skull Mountain earthquake in 1992 (DIRS 151945-CRWMS M&O 2000, p. 12.3-7 and Figure 12.3-4, p. F12.3-4), which had a Richter magnitude of 5.6 (DIRS 151945-CRWMS M&O 2000, p. 12.3-18). This seismic event occurred about 20 kilometers (12 miles) southeast of Yucca Mountain, about a day after the magnitude 7.3 earthquake at Landers, California, 300 kilometers (190 miles) south-southeast of Yucca Mountain. The Little Skull Mountain event caused no damage at Yucca Mountain, although some damage occurred at the Field Office Center in Jackass Flats (DIRS 151945-CRWMS M&O 2000, p. 12.3-18) about 5 kilometers (3 miles) north of the epicenter.

Seismic Hazard

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of

Group (Tiva Canyon, Yucca Mountain, Pah Canyon, and Topopah Spring tuffs), joints are subdivided into three groups based on their generating mechanism and time of occurrence: early cooling joints, later tectonic joints, and joints due to erosional unloading (DIRS 151945-CRWMS M&O 2000, pp. 4.7-5 to 4.7-7). Each type of joint exhibits different characteristics with respect to its length, orientation, and connectivity. The cooling and tectonic joints have similar orientations (generally running north-south), but cooling joints include irregularly spaced horizontal joints as well. Joints due to erosional unloading are variably oriented but tend predominantly east to west, cross-wise to the cooling and tectonic joints. Tectonic joints occur throughout the Paintbrush Group and cooling joints are identified in each of the welded units. In general, the highest joint frequencies and connectivities occur in the units of the Tiva Canyon and Topopah Spring tuffs and the lowest occur in the nonwelded Yucca Mountain and Pah Canyon tuffs. Most joints, particularly cooling joints, are confined to specific rock units and do not cross unit boundaries. They do not generally form through-going features like faults. Geologic, geoengineering, and hydrologic aspects of fractures are discussed in detail in the Yucca Mountain Site Description (DIRS 151945-CRWMS M&O 2000, pp. 4.6-17 to 4.6-19, 4.7-5 to 4.7-7, 4.7-36 to 4.7-40, and 8.9-1 to 8.9-15).

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Seismic Hazard

DOE based the design ground motion and fault displacement that could be associated with future earthquakes at Yucca Mountain on the record of historic earthquakes in the Great Basin, evaluation of prehistoric earthquakes based on investigations (trenching and detailed mapping) of the faults at Yucca Mountain, and observation of ground motions associated with modern earthquakes using the Southern Great Basin Seismic Network.

Experts have evaluated site data and other relevant information (including differing models) to assess where and how often future earthquakes will occur, how large they will be, how much offset will occur at the Earth's surface, and how ground motion will diminish as a function of distance. Two panels of scientific experts conducted the Probabilistic Seismic Hazard Analysis (DIRS 100354-USGS 1998, all); one panel characterized sources of future earthquakes and their potential for surface fault displacement and the second addressed ground motion for the Yucca Mountain region. The results of this analysis are hazard curves that show the ground motions and potential fault displacements plotted with annual frequency of being exceeded. These are used to determine the design-basis ground motions and to assess the postclosure performance of the site (DIRS 151945-CRWMS M&O 2000, pp. 12.4-3 to 12.4-7). Figure H-1 in Appendix H shows the summary hazard curve for horizontal peak ground acceleration generated from the analysis.

The expert assessments indicate that geologic fault displacement hazard is generally low. For locations not on a major block-bounding fault, displacements greater than 0.1 centimeter (0.04 inch) will be exceeded an average of less than once in 100,000 years, whereas the mean displacements that are likely to be exceeded on the block-bounding Bow Ridge and Solitario Canyon faults are 7.8 and 32 centimeters (3.1 and 13 inches), respectively (DIRS 151945-CRWMS M&O 2000, p. 12.3-86). Mitigating potential fault displacement effects would involve avoiding faults in laying out repository facilities (DIRS 151945-CRWMS M&O 2000, p. 12.3-92).

Ground motion studies have investigated the level of shaking produced at Yucca Mountain by both local and regional earthquakes, and have estimated expected ground motion from hypothetical earthquakes. These predictions of probable ground motion amplitudes and frequencies support preliminary design requirements (the Exploratory Studies Facility), and future studies will provide additional site-specific information on soil and rock properties that will enable refinement of preliminary results and facilitate design analyses to mitigate seismic risk to a potential repository (DIRS 101779-DOE 1998, Volume 1, pp. 2-86 and 2-87).

The seismic design basis for the repository specifies that structures, systems, and components important to safety should be able to withstand the horizontal motion from an earthquake with a return frequency of once in 10,000 years (annual probability of occurrence of 0.0001) (DIRS 103237-CRWMS M&O 1998, p. VII-3). A recent comprehensive evaluation of the seismic hazards associated with the site of the proposed repository (DIRS 100354-USGS 1998, Figure 7-4) concluded that a 0.0001-per-year earthquake would produce peak horizontal accelerations at a reference rock site at Yucca Mountain of about 0.53*g* (mean value). DOE needs to complete additional investigations of ground motion site effects before it can produce the final seismic design basis for the surface facilities.

A recent study published in *Science* magazine (DIRS 103485-Wernicke et al. 1998, all) claims that the crustal strain rates in the Yucca Mountain area are at least an order of magnitude higher than would be predicted from the Quaternary volcanic and tectonic history of the area. If higher strain rates are present, the potential volcanic and seismic hazards would be underestimated on the basis of the long-term geologic record.

As part of the Yucca Mountain site characterization activities, DOE established a 14-station, 50-kilometer (30-mile), geodetic array, centered on Yucca Mountain, and conducted surveys in 1983, 1984, and 1993. As interpreted by U.S. Geological Survey researchers (DIRS 103457-Savage et al. 1994, all), the surveys indicated no large strain accumulation and thus do not support the claims in DIRS 103485-Wernicke et al. (1998, all). The Yucca Mountain array was resurveyed by the U.S. Geological Survey in 1998

(DIRS 118952-Savage, Svarc, and Prescott 1999, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by DIRS 103485-Wernicke et al. (1998, all).

DOE is continuing to fund additional investigations on the crustal strain rate in the Yucca Mountain region through a grant to the University of Nevada. Dr. Wernicke of the California Institute of Technology (Cal Tech) continues to monitor conditions as a principal investigator under a subcontract, and a group at the University of Nevada at Reno is tasked with providing an independent evaluation of the assumptions and processing that support the Cal Tech results. This study involves 32 geodetic monument sites with continuous Global Positioning System measurements, a significant improvement over the study reported in *Science* in 1998. The first report (DIRS 156302-Marks 2001, all) from this effort was issued during 2001 and provided a status based on data collected through May 2001. According to the report, preliminary findings from this ongoing study are that strain is accumulating in the Yucca Mountain region, but at a notably lower rate than previously reported by DIRS 103485-Wernicke et al. (1998, all). Improved results are expected over the next year of the study, including a better characterization and explanation for the strain accumulation. DOE believes the results of this study will confirm the lower crustal strain rates as reported by the U.S. Geological Survey. However, if higher crustal strain rates are shown to exist, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (DIRS 103483-Weiss, Noble, and Larson 1996, p. 5-26).

DOE site investigations included evaluation of the potential for mineral and energy resources in the analyzed withdrawal area because the presence of such resources could lead to exploration and inadvertent *human intrusion* (see Chapter 5). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, Section 4.9) describes results of investigations that address relevant natural resources. Site characterization investigators identified no economic deposits of base or precious metals, industrial rocks or minerals, and energy resources, based on present use, extraction technology, and economic value of the resources (DIRS 151945-CRWMS M&O 2000, p. 4.9-12 to 4.9-14). DOE believes the potential for economically useful mineral or energy resources in the analyzed Yucca Mountain withdrawal area is low.

3.1.4 HYDROLOGY

This section describes the current hydrologic conditions in the Yucca Mountain region in terms of surface-water and groundwater system characteristics. The region of influence considered for surface water includes construction or land disturbance areas that could be susceptible to erosion, areas affected by permanent changes in surface-water flow, and areas downstream of the proposed repository that could be affected by eroded soil or potential spills of contaminants. The groundwater region of influence includes aquifers that would underlie areas of construction and operation, aquifers that could be sources of water for construction and operations, and aquifers downgradient of the proposed repository that repository use, including long-term releases, could affect. Section 3.1.4.1 describes surface-water conditions, and Section 3.1.4.2 describes groundwater conditions.

(DIRS 118952-Savage, Svarc, and Prescott 1999, all). After correction for deformation associated with the Little Skull Mountain earthquake, the data continue to indicate a strain rate about an order of magnitude lower than that reported by DIRS 103485-Wernicke et al. (1998, all).

DOE is continuing to fund additional investigations on the crustal strain rate in the Yucca Mountain region through a grant to the University of Nevada. Dr. Wernicke of the California Institute of Technology (Cal Tech) continues to monitor conditions as a principal investigator under a subcontract, and a group at the University of Nevada at Reno is tasked with providing an independent evaluation of the assumptions and processing that support the Cal Tech results. This study involves 32 geodetic monument sites with continuous Global Positioning System measurements, a significant improvement over the study reported in *Science* in 1998. The first report (DIRS 156302-Marks 2001, all) from this effort was issued during 2001 and provided a status based on data collected through May 2001. According to the report, preliminary findings from this ongoing study are that strain is accumulating in the Yucca Mountain region, but at a notably lower rate than previously reported by DIRS 103485-Wernicke et al. (1998, all). Improved results are expected over the next year of the study, including a better characterization and explanation for the strain accumulation. DOE believes the results of this study will confirm the lower crustal strain rates as reported by the U.S. Geological Survey. However, if higher crustal strain rates are shown to exist, DOE will reassess the volcanic and seismic hazard at Yucca Mountain.

3.1.3.4 Mineral and Energy Resources

The southern Great Basin contains valuable or potentially valuable mineral and energy resources, including deposits with past or current production of gold, silver, mercury, base metals, and uranium. The proximity of known deposits and the identification of similar geologic features at Yucca Mountain have led some investigators to propose that the analyzed Yucca Mountain land withdrawal area (see Figure 3-2) could have the potential for mineral resources (DIRS 103483-Weiss, Noble, and Larson 1996, p. 5-26).

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The hydrologic system in the Yucca Mountain region is characterized and influenced by a very dry climate, limited surface water [annual average precipitation of about 10 to 25 centimeters (4 to 10 inches) (Section 3.1.2.2), potential evaporation of almost 170 centimeters (66 inches) per year (DIRS 101779-DOE 1998, Volume 1, p. 2-29)], and deep aquifers. Important characteristics of the hydrologic system include drainages and streambeds, streams, springs, and playa lakes. In addition, water quantity and quality are important characteristics. Yucca Mountain is in the Alkali Flat-Furnace Creek groundwater basin of the larger Death Valley Regional Groundwater Flow System. Death Valley is a terminal hydrologic basin; surface water and groundwater cannot leave except by *evapotranspiration* (DIRS 100465-Luckey et al. 1996, p. 30). Important characteristics of the groundwater system include *recharge* zones (areas where water infiltrates from the surface and reaches the saturated zone), discharge points (locations where groundwater reaches the surface), unsaturated zones (the portion of the groundwater system above the water table), saturated zones (the portion of the groundwater system below the water table), and aquifers (water-bearing layers of rock that provide water in usable quantities). In combination, these characteristics define the quantity and quality of the available groundwater. This section also describes groundwater use as part of the system.

EVAPOTRANSPIRATION

Evapotranspiration is the loss of water by evaporation from the soil and other surfaces, including evaporation of moisture emitted or transpired from plants.

3.1.4.1 Surface Water

3.1.4.1.1 *Regional Surface Drainage*

Yucca Mountain is in the southern Great Basin, which generally lacks perennial streams and other surface-water bodies. The Amargosa River system drains Yucca Mountain and the surrounding areas (Figure 3-11). Although referred to as a river, the Amargosa and its tributaries (the washes that drain to it) are dry along most of their lengths most of the time. Exceptions include short stretches where groundwater discharges to or converges with the channel (DIRS 151945-CRWMS M&O 2000, p. 7.1-3); examples are near Beatty, Nevada; south of Tecopa, California; and in southern Death Valley, California. The river drains an area of about 8,000 square kilometers (3,100 square miles) by the time it reaches Tecopa (DIRS 103090-Bostic et al. 1997, pp. 103 and 112), and its course extends roughly 100 kilometers (60 miles) farther before it ends in the Badwater Basin in Death Valley (DIRS 151945-CRWMS M&O 2000, p. 7.1-2 and Figures 7.1-1 and 7.1-4, pp. F7.1-1 and F7.1-4), which is more than 80 meters (260 feet) below sea level (DIRS 151945-CRWMS M&O 2000, p. 2.2-1). The nearest surface-water impoundments are Peterson Reservoir, Crystal Reservoir, Lower Crystal Marsh, and Horseshoe Reservoir.

The largest of these is Crystal Reservoir, a manmade impoundment at Ash Meadows, which captures the discharge from several springs in the area and has a capacity of 1.8 million cubic meters (1,500 acre-feet). Crystal Reservoir and other smaller pools in Ash Meadows drain to the Amargosa River through Carson Slough (DIRS 151945-CRWMS M&O 2000, p. 7.1-2).

3.1.4.1.2 *Yucca Mountain Surface Drainage*

Occurrence. No perennial streams, natural bodies of water (DIRS 151945-CRWMS M&O 2000, pp. 7.1-2 and 7.1-3), or naturally occurring wetlands (DIRS 104592-CRWMS M&O 1999, p. 2-14) occur at Yucca Mountain or in the analyzed land withdrawal area. Fortymile Wash, a major wash that flows to the Amargosa River, drains the eastern side of Yucca Mountain (Figure 3-12) (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). The primary washes draining to Fortymile Wash at Yucca Mountain include Yucca Wash to the north; Drill Hole Wash, which, together with its tributary, Midway Valley Wash, drains most of the repository site; and Busted Butte (Dune) Wash to the south. The western side of Yucca Mountain

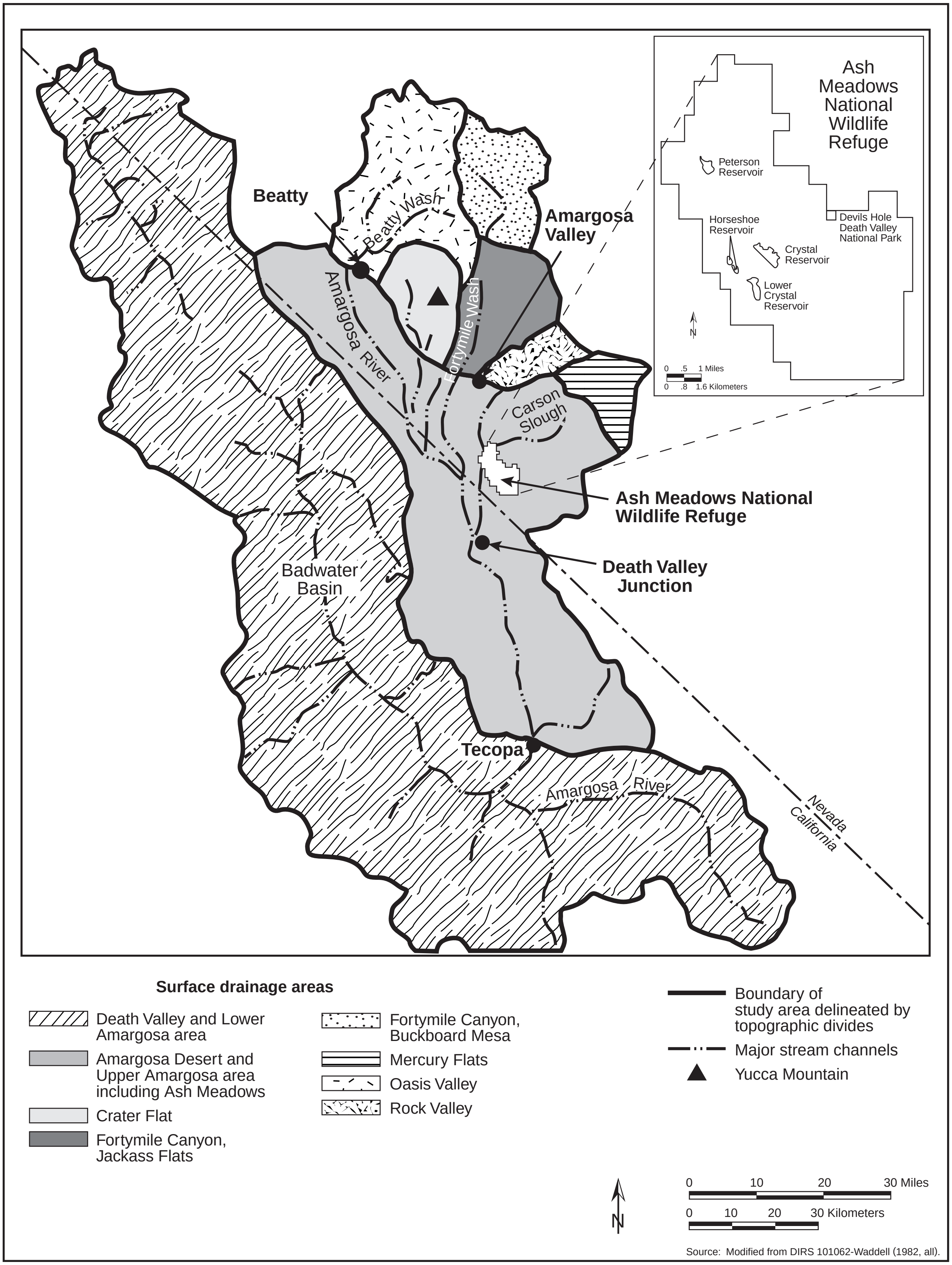

Figure 3-11. Surface areas drained by the Amargosa River and its tributaries.

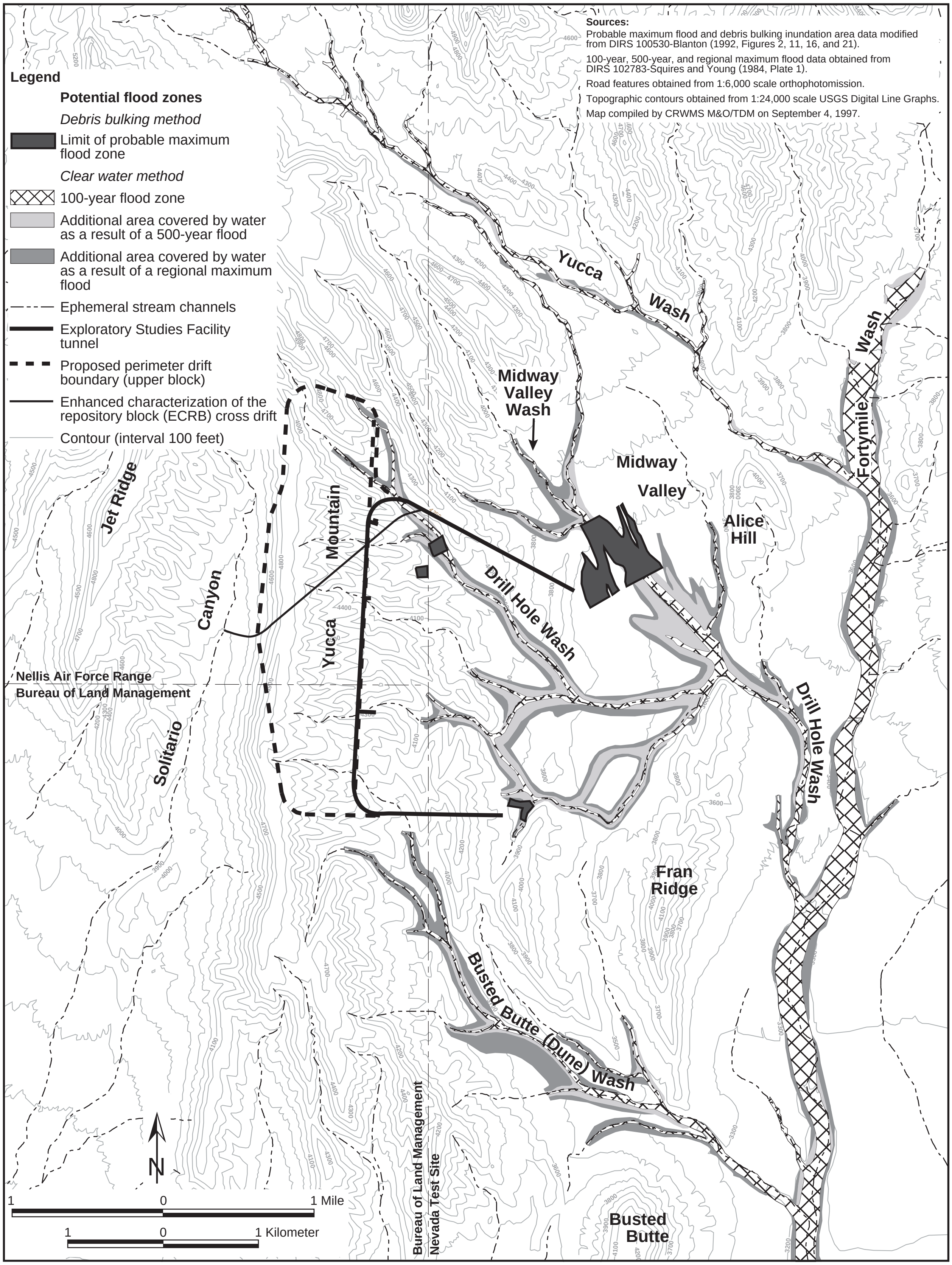

Figure 3-12. Site topography and potential flood areas.

is drained through Solitario Canyon Wash and Crater Flat, both of which eventually drain to the Amargosa River (DIRS 151945-CRWMS M&O 2000, p. 7.1-2). In this area, most of the water from summer storms is lost relatively quickly to evapotranspiration unless a storm is intense enough to produce runoff or subsequent storms occur before the water is lost (DIRS 151945-CRWMS M&O 2000, p. 7.5-1). Evapotranspiration is lower during the winter, when water from precipitation or melting snow has a better chance to result in stream flow.

Thunderstorms in the area can be local and intense, creating runoff in one wash while an adjacent wash receives little or no rain (DIRS 151945-CRWMS M&O 2000, p. 7.1-3). In rare cases, however, storm and runoff conditions can be extensive enough to result in flow being present throughout the drainage system. DIRS 155679-Glancy and Beck (1998, all) documented conditions during March 1995 and February 1998 where Fortymile Wash and the Amargosa River flow simultaneously through their primary channels to Death Valley. The 1995 event represented the first documented case of this flow condition. The 1995 event involved the higher recorded flows. The peak flow near the location where the existing Yucca Mountain access road crosses Fortymile Wash was reported as about 100 cubic meters (3,500 cubic feet) per second (DIRS 155679-Glancy and Beck 1998, p. 7). This flow is much less than that calculated as the *100-year flood* event for Fortymile Wash (as discussed in the next paragraph). The occurrence of flow throughout the drainage, however, might be a more unusual event because it would require the generation of runoff over a much larger area than the Fortymile Wash drainage, and in the same timeframe.

Flood Potential. Although flow in most washes is rare, the area is subject to flash flooding from intense summer thunderstorms or sustained winter precipitation (DIRS 151945-CRWMS M&O 2000, p. 7.3-1). When it occurs, intense flooding can include mud and debris flows in addition to water runoff (DIRS 100530-Blanton 1992, p. 2). Table 3-9 lists peak discharges for estimated floods along the main washes at Yucca Mountain, a value for a regional maximum flood. In addition to the flood estimates listed in the table, DOE used another estimating method, the *probable maximum flood* methodology [based on American National Standards Institute and American Nuclear Society Standards for Nuclear Facilities (DIRS 103071-ANS 1992, all)] to generate another maximum flood value for washes adjacent to the existing facilities and operations at the North and South Portals (DIRS 100530-Blanton 1992, all; DIRS 108883-Bullard 1992, all). The flood value this method generates, which includes a bulking factor to account for mud and debris (including boulder-size materials), is the most severe reasonably possible for the location under evaluation and is larger than the regional maximum flood listed in Table 3-9 (DIRS 151945-CRWMS M&O 2000, pp. 7.3-3 and 7.3-4). DOE used the probable maximum flood values to predict the areal extent of flooding and to determine if facilities and operations are at risk of flood damage.

PREDICTED FLOODS

100-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 100 years.

500-year flood: The magnitude of peak discharge at any point on a river or drainage channel that can be expected to occur or be exceeded, on average, once in 500 years.

Regional maximum flood: The magnitude of a peak discharge based on data from extreme floods, in this case, occurring elsewhere in Nevada and in nearby states.

Probable maximum flood: The hypothetical peak discharge considered to be the most severe reasonably possible based on a probable maximum precipitation and other factors favorable for runoff.

Figure 3-12 shows the extent of estimated floods calculated for the proposed repository before the construction of the Exploratory Studies Facility. It shows the area that the estimated 100- and 500-year floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

Table 3-9. Estimated peak discharges along washes at Yucca Mountain.[a]

Name	Drainage area (square kilometers)[b]	Peak discharge 100-year flood (cubic meters per second)[c]	Peak discharge 500-year flood (cubic meters per second)	Regional maximum flood (cubic meters per second)
Fortymile Wash	810	340	1,600	15,000
Busted Butte (Dune) Wash	17	40	180	1,200
Drill Hole Wash[d]	40	65	280	2,400
Yucca Wash	43	68	310	2,600

a. Source: DIRS 102783-Squires and Young (1984, p. 2).
b. To convert square kilometers to square miles, multiply by 0.3861.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. Includes Midway Valley and South Portal Washes as tributaries—North and South Portal Areas.

Along Busted Butte (Dune) and Drill Hole Washes, the *500-year flood* would exceed stream channels at several places, and the probable maximum flood would inundate broad areas in Midway Valley Wash near the North Portal. None of the identified flood estimates predicts water levels high enough to reach either the North or South Portal opening to the subsurface facilities (DIRS 100530-Blanton 1992, pp. 4 and 7), which would be at either end of the Exploratory Studies Facility tunnel shown in the figure.

The U.S. Geological Survey (DIRS 103469-Thomas, Hjalmarson, and Waltemeyer 1997, all) recently published a revised methodology for calculating peak flood discharges in the southwestern United States. A preliminary evaluation indicates that the methodology, if appropriate for use, could result in estimates for 100-year floods that are larger than those listed in Table 3-8 and shown in Figure 3-12. However, the new methodology affects only the 100-year flood estimate, so discharge numbers and expanded inundation lines resulting from its use would be within the bounds set by the 500-year flood.

DOE has prepared a *floodplain* assessment for the Proposed Action in accordance with the requirements of 10 CFR Part 1022. Appendix L contains the floodplain assessment.

Surface-Water Quality. Samples of stream waters in the Yucca Mountain region have been collected and analyzed for their general chemical characteristics. Because surface-water flows are rare and in immediate response to storms, data from sampling events are sparse. Results of the surface-water sample analyses (Table 3-10) bear some resemblance to those from groundwater samples, as discussed in Section 3.1.4.2.2, because both contain bicarbonate as a principal component. However, in general, the groundwaters have a higher mineral content, suggesting more interaction between rock and water (see Section 3.1.4.2.2, Tables 3-13 and 3-17).

3.1.4.2 Groundwater

This section discusses groundwater, first on a regional basis and then in the Yucca Mountain vicinity. Many studies have been conducted on the groundwater system under and surrounding Yucca Mountain. These studies provide a firm basis of understanding of the hydrology of the region. However, because floods would inundate as well as the inundation area for the most conservative (highest) of the estimated maximum floods. As indicated on the figure, the partial or discontinuous inundation areas in Midway Valley Wash and the upper reaches of Drill Hole Wash are based on the probable maximum flood values derived in accordance with guidelines of the American National Standards Institute and American Nuclear Society; for other areas, the most extensive flood zones are based on the regional maximum flood levels listed in Table 3-9. The figure also shows that all floods along Fortymile Wash and Yucca Wash would remain within existing stream channels.

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Table 3-10. Chemistry of surface water in the Yucca Mountain region.[a]

Chemical[b]	Range of chemical composition
pH	7.8 - 8.4
Total dissolved solids (milligrams per liter)	45.0 - 123
Calcium (milligrams per liter)	6.7 - 28.0
Magnesium (milligrams per liter)	0.7 - 3.9
Potassium (milligrams per liter)	3.2 - 11.0
Sodium (milligrams per liter)	2.4 - 16.0
Bicarbonate (milligrams per liter)	32.0 - 109
Chloride (milligrams per liter)	1.3 - 10.0
Sulfate (milligrams per liter)	4.1 - 24.0
Silica (milligrams per liter)	4.5 - 36.0

a. Source: DIRS 151945-CRWMS M&O (2000, Table 5.3-3, p. T5.3-7).
b. Based on 18 samples from 15 different surface-water locations (12 involve a single sampling event and 3 involve two sampling events) collected from 1984 to 1995. One milligram per liter is equivalent to one part per million.

groundwater systems are complex and difficult to study, there are differences of opinion among experts related to interpreting available data and describing certain aspects of the Yucca Mountain groundwater system. Therefore, this section also discusses the various views on the groundwater system under Yucca Mountain, where viewpoints differ.

3.1.4.2.1 *Regional Groundwater*

The groundwater flow system of the Death Valley region is very complex, involving many *aquifers* and confining units. Over distance, these layers vary in their characteristics or even their presence (DIRS 151945-CRWMS M&O 2000, pp. 9.2-5 to 9.2-10). In some areas confining units allow considerable movement between aquifers; in other areas confining units are sufficiently impermeable to support artesian conditions (where water in a lower aquifer is under pressure in relation to an overlying confining unit; when intersected by a well, the water will rise up the borehole).

In general, the principal water-bearing units of the Death Valley regional groundwater flow system (or simply Death Valley region) are grouped in three types of saturated hydrogeologic units: basin-fill alluvium (or alluvial aquifer), volcanic aquifers, and carbonate aquifers (DIRS 151945-CRWMS M&O 2000, pp. 9.2-23 and 9.2-24). An alluvial aquifer is in a *permeable* body of sand, silt, gravel, or other detrital material deposited primarily by running water. Volcanic and carbonate aquifers are in permeable units of *igneous* (of volcanic origin) and carbonate (limestone or dolomite) rock, respectively. The mountainous area that makes up the north-central portion of the Death Valley region that includes the Yucca Mountain area is often underlain by volcanic rocks and associated volcanic aquifers. The valley or basin areas to the south and southeast of Yucca Mountain contain alluvial aquifers, including those beneath the Amargosa Desert. Carbonate aquifers are regionally extensive and generally occur at large depths below volcanic aquifers or alluvial aquifers (DIRS 151945-CRWMS M&O 2000, p. 9.6-2). The discussion of groundwater at Yucca Mountain describes the position of the various aquifers and confining units in relation to each other and to stratigraphic units.

The alluvial aquifers below the Amargosa Desert receive underflow (groundwater movement from one area to another) from groundwater basins to the north as well as from basin areas to the east and, therefore, contain a mixture of water from several different aquifers (DIRS 151945-CRWMS M&O 2000, pp. 9.2-16 to 9.2-18). For example, the volcanic aquifers beneath Yucca Mountain are believed to provide inflow to the alluvial aquifers beneath the Amargosa Desert. In addition, the springs in the Ash Meadows area are fed in part by the carbonate aquifers (DIRS 101167-Winograd and Thordarson 1975, p. C53) and what is not discharged through the springs flows into groundwater moving through the alluvial aquifers at the southeast end of the Amargosa Desert and then discharges at Alkali Flat (Franklin Lake Playa) or continues as groundwater into Death Valley (DIRS 151945-CRWMS M&O 2000, pp. 9.2-17 and 9.2-18). There is also evidence that indicates a carbonate aquifer might be present below the volcanic sequence, extending from eastern Yucca Mountain south into the Amargosa Desert (DIRS 100465-Luckey et al. 1996, pp. 32 and 40).

HYDROGEOLOGIC TERMS

Permeability: Describes the ease or difficulty with which water passes through a given material. Permeable materials allow fluids to pass through readily, while less permeable materials inhibit the flow of fluids.

Aquifer: A permeable water-bearing unit of rock or sediment that yields water in a usable quantity to a well or spring.

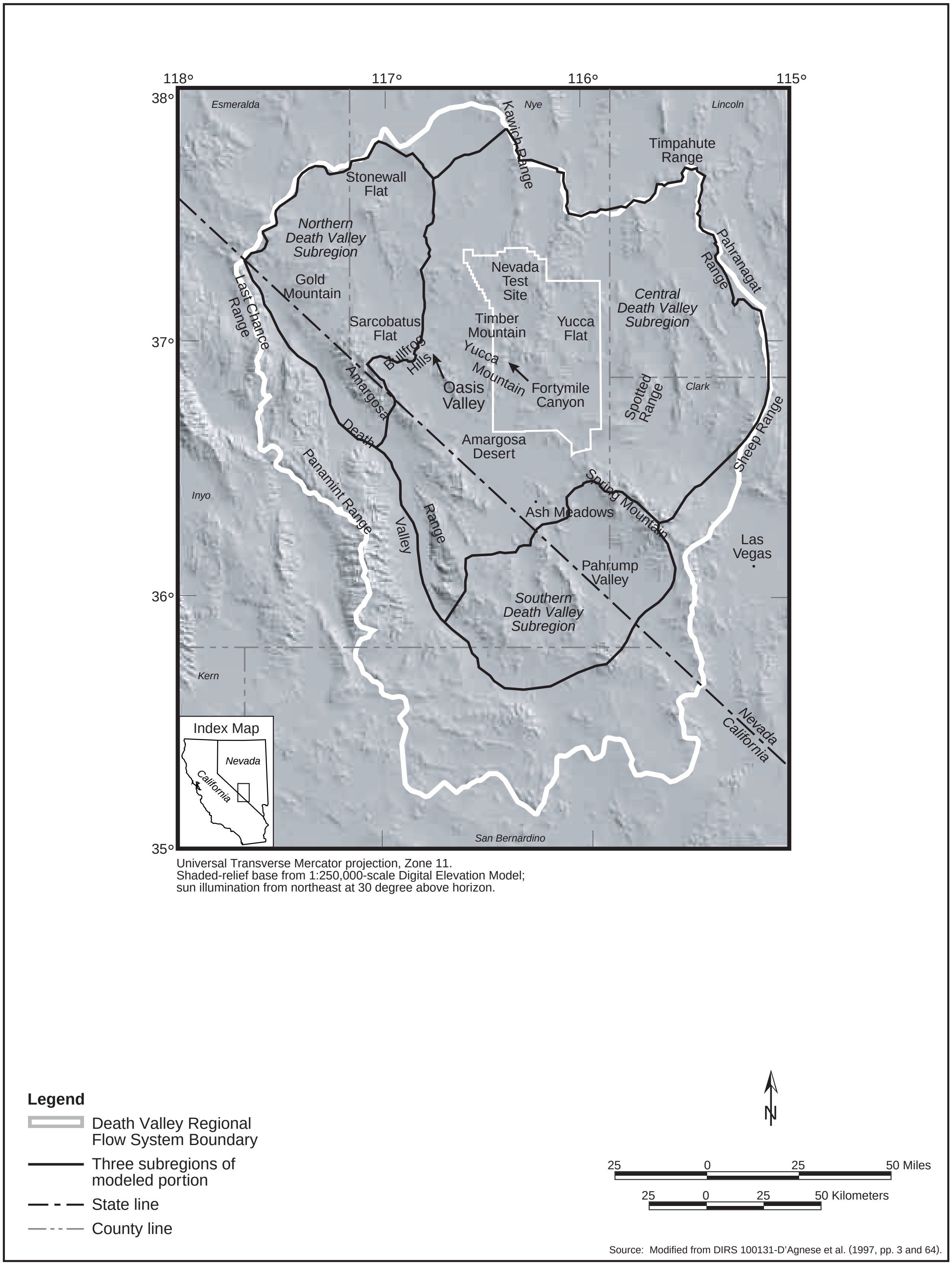
Saturated zone: The area below the water table where all spaces (fractures and rock pores) are completely filled with water.

Confining unit (or aquitard): A rock or sediment unit of relatively low permeability that retards the movement of water in or out of adjacent aquifers.

Inflow: Sources of water flow into a groundwater system such as surface infiltration (recharge) or contributions from other aquifers.

Basins. The Death Valley regional groundwater flow system (Figure 3-13) or region covers about 50,000 square kilometers (19,000 square miles) (DIRS 151945-CRWMS M&O 2000, p. 9.2-3). Straddling the Nevada-California border, this flow system includes several prominent valleys (Amargosa Desert, Pahrump Valley, and Death Valley) and their separating mountain ranges and extends north to the Kawich Valley, encompassing all of the Nevada Test Site (DIRS 151945-CRWMS M&O 2000, Figures 9.2-1 and 9.2-2, pp. F9.2-1 and F9.2-2). The major recharge areas are mountains in the east and north portions of the region (DIRS 151945-CRWMS M&O 2000, pp. 9.2-11 and 9.2-15). The discharge points are primarily to the south and include the southernmost discharge points in Death Valley and intermediate points such as Ash Meadows in the Amargosa Desert and Alkali Flat (DIRS 151945-CRWMS M&O 2000, p. 9.2-13). Therefore, flow is primarily to the west or south. Figure 3-13 shows a slightly reduced outline for the regional flow system that some Yucca Mountain Site Characterization Project modeling efforts (for example, DIRS 100131-D'Agnese et al. 1997, all) have used as the boundary. This reduced area is divided into the Northern, Central, and Southern Death Valley subregions. The Central Death Valley subregion contains the area of Yucca Mountain.

Hydrologic investigations of the Death Valley region date back to the early 1900s, with early work performed primarily by the U.S. Geological Survey (DIRS 100131-D'Agnese et al. 1997, p. 4). More recently, studies by both the U.S. Geological Survey and the State of Nevada have included efforts to collect and compile water-level data from regional wells (DIRS 151945-CRWMS M&O 2000, p. 9.2-39). DOE has collected groundwater-level data from wells at Yucca Mountain and in neighboring areas on a routine basis since 1983, and has used the levels to which water rises in these wells—called the *potentiometric surface*—to map the slope of the groundwater surface and to determine the direction of flow. Figure 3-14 is a potentiometric surface map of the Death Valley regional groundwater flow system. Based on these and other data, groundwater in aquifers below Yucca Mountain and in the surrounding region flows generally south toward discharge areas in the Amargosa Desert and Death Valley (Figure 3-15). The area around Yucca Mountain is in the central subregion of the Death Valley region, and this subregion has three groundwater basins: (1) Ash Meadows, (2) Alkali Flat-Furnace Creek, and (3) Pahute Mesa-Oasis Valley (DIRS 102893-Rush 1971, pp. 10 and 11; DIRS 101062-Waddell 1982, pp. 13 to 20; DIRS 100465-Luckey et al. 1996, pp. 28-30; and DIRS 100131-D'Agnese et al. 1997, p. 65). The aquifers below Yucca Mountain have been included in the Alkali Flat-Furnace Creek groundwater basin because of evidence that the groundwater discharges mainly at Alkali Flat (Franklin Lake Playa) and potentially to the Furnace Creek Wash area of Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18).



Universal Transverse Mercator projection, Zone 11.
Shaded-relief base from 1:250,000-scale Digital Elevation Model;
sun illumination from northeast at 30 degree above horizon.

Source: Modified from DIRS 100131-D'Agnese et al. (1997, pp. 3 and 64).

Figure 3-13. Boundaries of Death Valley regional groundwater flow system.

Universal Transverse Mercator projection, Zone 11. Shaded-relief base from 1:250,000-scale Digital Elevation Model; sun illumination from northeast at 30 degrees above horizon

Legend

Death Valley Regional flow system boundary

1,000 Potentiometric contour - show altitude of potentiometric surface. Contour interval 100 meters. Datum is sea level.

N

25 0 25 Kilometers

25 0 25 Miles

Source: Modified from DIRS 100131-D'Agnese et al. (1997, Figure 27).

Figure 3-14. Estimated potentiometric surface of the Death Valley region.

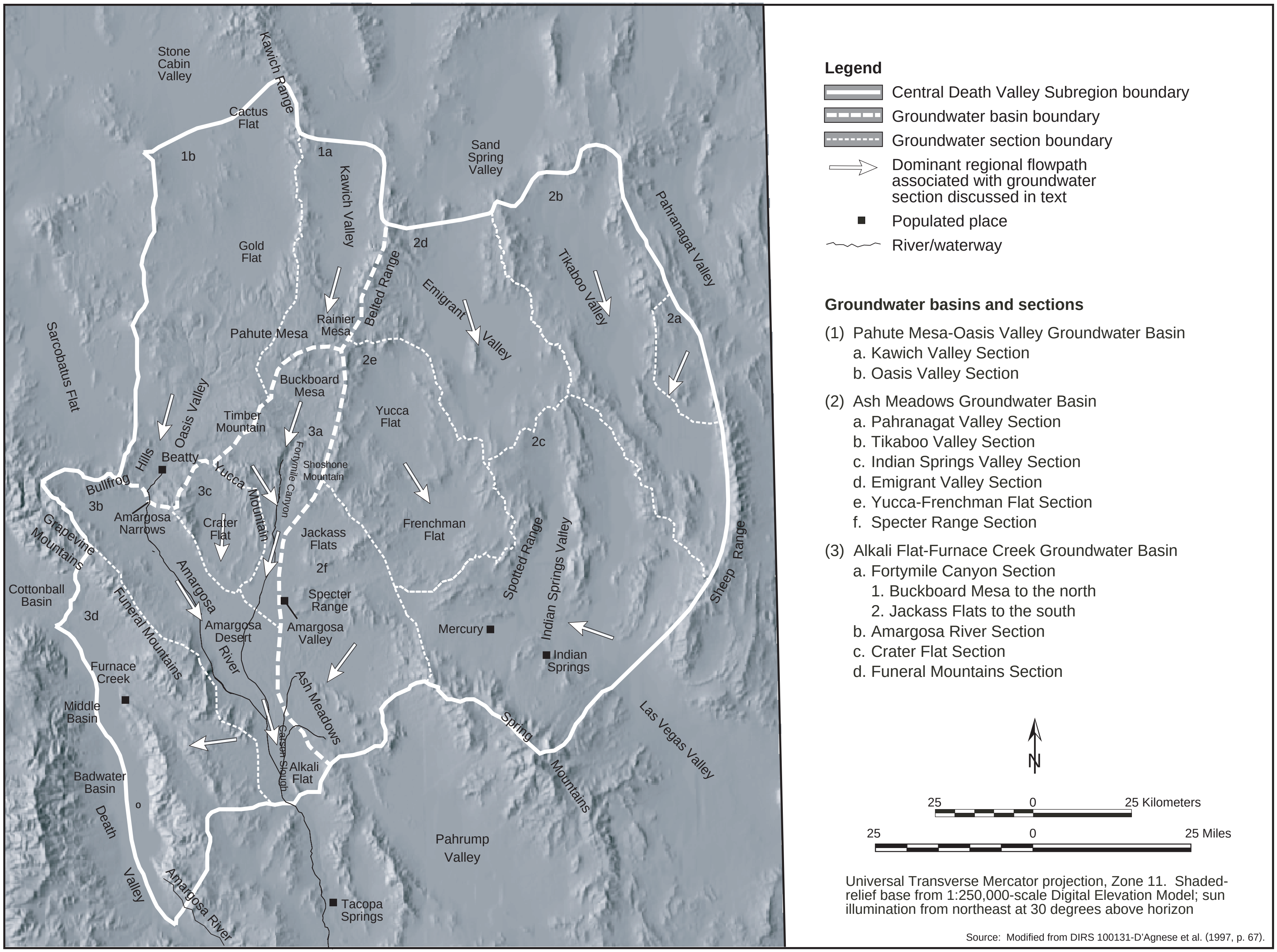


Figure 3-15. Groundwater basins and sections of the Central Death Valley subregion.

The Ash Meadows groundwater basin is the easternmost of the three basins that make up the Central Death Valley subregion. It underlies eastern portions of the Nevada Test Site (Yucca Flat, Frenchman Flat, Mercury Valley, Rock Valley), parts of Shoshone Mountain, Rainier Mesa to the north, and the Ash Meadows area of the Amargosa Desert in the south. Inflow is principally from the Spring Mountains, Pahranagat Range, Sheep Range, and Pahranagat Valley in the eastern portion of the basin (DIRS 100131-D'Agnese et al. 1997, pp. 67 and 68). Outflow is basically in the form of discharge to the surface and underflow to the lower portion of the Alkali Flat-Furnace Creek groundwater basin. The primary discharge point for this groundwater basin is Ash Meadows, where springs occur in a line along a major fault (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). Estimates of discharge at Ash Meadows range from 21 million to 37 million cubic meters (17,000 to 30,000 acre-feet) per year (DIRS 103022-Walker and Eakin 1963, p. 24; DIRS 100131-D'Agnese et al. 1997, p. 46).

The Pahute Mesa-Oasis Valley groundwater basin includes Oasis Valley, Gold Flat, the southern parts of Cactus Flat and Kawich Valley, and the western portion of Pahute Mesa. Recharge areas are primarily in the north in the Belted and Kawich Ranges and Pahute Mesa, but include Timber Mountain and the Bullfrog Hills, and along the Amargosa River and its tributaries (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). Subsurface outflow is into the Amargosa Desert of the Alkali Flat-Furnace Creek groundwater basin, and has been estimated at about 0.49 million cubic meters (400 acre-feet) per year (DIRS 106695-Malmberg and Eakin 1962, p. 26).

The Alkali Flat-Furnace Creek groundwater basin is bordered on the northwest by the Pahute Mesa-Oasis Valley basin and on the east by the Ash Meadows basin. This groundwater basin includes portions of the Nevada Test Site (parts of Rainier Mesa, Pahute Mesa, and Buckboard Mesa to the north, Shoshone Mountain, Yucca Mountain, and Jackass Flats in the southern half), Crater Flat in the west, and part of Death Valley and the central part of the Amargosa Desert in the south (DIRS 100131-D'Agnese et al. 1997, pp. 67 to 69). As shown in Figure 3-15, this basin includes the groundwater area designated as the Fortymile Canyon Section, which includes the area of Buckboard Mesa to the north and a portion of Jackass Flats to the south. Groundwater moving beneath the proposed repository site is in the Fortymile Canyon section.

In the immediate vicinity of Yucca Mountain, sources of recharge to the groundwater include Fortymile Wash and precipitation that infiltrates the surface. However, these local sources are not among the primary sources of recharge in the area that makes up the Alkali Flat-Furnace Creek groundwater basin. The primary sources of surface recharge in this area are infiltration on Pahute Mesa, Rainier Mesa, Timber Mountain, and Shoshone Mountain to the north (DIRS 151945-CRWMS M&O 2000, p. 9.2-18), and the Grapevine and Funeral Mountains to the south (DIRS 100131-D'Agnese et al. 1997, p. 68). One numerical model of infiltration for Yucca Mountain used energy- and water-balance calculations to obtain an average infiltration rate of 4.7 millimeters (0.2 inch) a year over the potential repository area for the current climate (DIRS 151945-CRWMS M&O 2000, Table 8.2-9, p. T8.2-7). This represents less than 3 percent of an average annual precipitation rate of about 200 millimeters (8 inches) used in the model for the crest at Yucca Mountain. In comparison, areas such as Pahute Mesa, Timber Mountain, and Shoshone Mountain receive more precipitation (DIRS 103021-DOE 1997, Plate 1) and have higher estimated percentages of precipitation infiltrating deep into the ground and eventually becoming recharge to the aquifer.

Water infiltrating at Yucca Mountain and becoming recharge to the groundwater would join with water in the Fortymile Canyon Section (Figure 3-15). From there the general direction of groundwater flow is to the Amargosa Desert basin and then Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18). There have been many estimates of the amount of groundwater moving along this path. One study (DIRS 103016-State of Nevada 1971, p. 50) that is still used extensively by the State of Nevada in its groundwater planning efforts estimated annual groundwater movement of 10 million cubic meters (8,100 acre-feet) from the area of Jackass Flats to the Amargosa Desert and 23.4 million cubic meters

(19,000 acre-feet) from the Amargosa Desert to Death Valley. DOE studies indicate that the quantity of water that might move through a repository area of 10 square kilometers (2,500 acres) (the largest repository footprint under any of the operating modes), assuming 4.7 millimeters (0.2 inch) of infiltration per year, would be about 0.2 percent of the estimated 23.4 million cubic meters (19,000 acre-feet) that moves from the Amargosa Desert to Death Valley on an annual basis.

DOE has performed a study (DIRS 157072-BSC 2001, all) to develop an "expected-case" model of groundwater flow in the saturated zone from beneath Yucca Mountain. The primary objective of the study was to evaluate the effects of several specific elements of conservatism in the groundwater flow model used in the Total System Performance Assessment (TSPA; see Chapter 5 and Appendix I). The study looked at the physical parameter values used in that model, for example the diffusion coefficient, porosity for fractured tuffs, and *permeability* for alluvial materials. It also looked at the location assumed in the TSPA where the groundwater flow path in the saturated zone changes from tuff to alluvial material. The recent effort looked at data collected on several specific parameters that would support what were felt to be more realistic, less conservative values. The expected-case model was run with these parameters changed and assuming a nonsorbing tracer was released as a point source to the water table beneath the proposed repository. The results of these model runs indicated it would take in the range of 1,000 to 1,500 years for 50 percent of the tracer to reach a distance of 20 kilometers (12 miles) in the groundwater flow path (DIRS 157072-BSC 2001, Figure 10, p. 43). Some of the tracer would find its way to faster pathways; some would take longer to travel the distance. DOE believes these estimates of groundwater travel time in the saturated zone represent reasonable estimates of what occurs in the natural setting.

As water in the Alkali Flat-Furnace Creek groundwater basin moves south through the Amargosa Desert, eastern portions of the flow are joined by underflow from the Ash Meadows groundwater basin (DIRS 101779-DOE 1998, Volume 1, pp. 2-56 to 2-58). The line of springs formed by discharge from the Ash Meadows groundwater basin provides much of the boundary between the two basins (DIRS 151945-CRWMS M&O 2000, p. 9.2-17). In this area there is a marked decline of about 64 meters (210 feet) in water table elevation between Devils Hole and Carson Slough, approximately 6.4 kilometers (4 miles) to the west (DIRS 103415-Dudley and Larson 1976, p. 23). This elevation decline indicates that the potential groundwater flow is from Ash Meadows toward the Alkali Flat-Furnace Creek groundwater basin, rather than the opposite. The primary groundwater discharge point for this groundwater basin is Alkali Flat (Franklin Lake Playa) as indicated by the potentiometric surface (or slope) of the groundwater and hydrochemical data. A small portion could move toward discharge points in the Furnace Creek area of Death Valley (DIRS 151945-CRWMS M&O 2000, p. 9.2-18).

Different researchers have speculated that the general flow boundaries of the three groundwater basins in the Central Death Valley subregion are in slightly different locations (DIRS 100131-D'Agnese et al. 1997, p. 59). Some studies [for example, DIRS 101062-Waddell (1982, p. 15)] have placed the Kawich Valley area in the Alkali Flat-Furnace Creek groundwater basin rather than in the Pahute Mesa-Oasis Valley groundwater basin as shown in Figure 3-15. This uncertainty in general flow boundaries is a reflection of the complex groundwater flow systems in the Death Valley region. The differing interpretations of the groundwater basin boundaries do not, however, disagree on the relative location of the aquifers below Yucca Mountain, which are consistently placed in the central Alkali Flat-Furnace Creek basin.

To reduce uncertainties, studies of the regional groundwater flow system are continuing. This is particularly true of that portion of the flow system that is downgradient of Yucca Mountain. Nye County, under a Cooperative Agreement with DOE, has implemented the Early Warning Drilling Program to install a series of wells in the Amargosa Valley area and the southern part of the Nevada Test Site. The purpose of this program is to characterize and monitor the saturated zone along possible transport pathways from Yucca Mountain. At the time this document was prepared, plans were underway to extend this program, which was originally set at 3 years (with a scheduled end date of November 2001). Under terms of the agreement, Nye County has had the responsibility to drill, test, and monitor a series of shallow and deep wells to investigate the upper volcanic or alluvial aquifers and the deep carbonate aquifer. The objective of the work is to determine aquifer characteristics, water chemistries, and flow paths. The County provides DOE splits of all samples collected and copies of all data obtained. DOE will continue to study the saturated zone south of Yucca Mountain through the simultaneous collection of data from this program and the use of data obtained by Nye County. In addition, a set of wells will be installed in Fortymile Wash to help identify the extent of the alluvium and valley fill along the potential flow path. Some of these wells will also be used to support an Alluvial Testing Complex, where aquifer and tracer tests in the alluvium and valley fill will be conducted. DIRS 156115-NWRPO (2001, all) described its efforts for Fiscal Years 1996 to 2001 in an August 2001 report prepared for DOE. Some of the groundwater findings discussed in this report include the following:

- Valley-fill deposits in the Amargosa Desert Area are very complex. Subsurface investigations have shown evidence of groundwater compartments as a result of faulting in the underlying rock. The conceptual hydrogeological model being developed from this information suggests that these compartments and boundaries between compartments serve either as groundwater flow pathways or as barriers. However, with several exceptions, the number and locations of compartments have not yet been well defined.

- Water level monitoring and temperature logs in wells suggest an upward gradient from underlying carbonate basement rocks into overlying valley-fill sediments.

- Evidence of transient (that is, varying over time) flow conditions in the past 50 years suggests it might be appropriate to calibrate groundwater flow models to transient flow conditions rather than the assumed steady-state conditions.

Although the Nye County report discusses these and other findings, Nye County and DOE have shared test results and data throughout the program. DOE has used and will continue to use the data collected from the Nye County and alluvial testing programs to refine its understanding of flow and transport mechanics south of Yucca Mountain. The information gained from these and other studies will be used to evaluate the accuracy and adequacy of similar information used in assessing the long-term performance of the proposed repository. The new information will also be used, as appropriate, in future iterations of conceptual and numerical models supporting the long-term performance assessment (see Chapter 5).

Use. Table 3-11 summarizes groundwater use in the Yucca Mountain region. The *hydrographic areas* listed in the table are basically a finer division of the subregions and groundwater basins discussed above; their locations are roughly consistent with the sectional divisions shown in Figure 3-15. These locations do not precisely match the groundwater area designations described in the preceding discussion because hydrographic areas generally reflect topographic divides (such as mountain ranges and valleys) that in some cases do not correspond to divides based on groundwater movement. The hydrographic area designations are important because the State of Nevada uses them as the basic units in its water planning and appropriations efforts.

DOE has been using small amounts of Jackass Flats hydrographic area groundwater for Nevada Test Site operations, and Yucca Mountain activities have contributed to water use from this source. Most water use in the Alkali Flat-Furnace Creek groundwater basin, however, occurs south of Yucca Mountain, from the Amargosa Desert alluvial aquifer (DIRS 151945-CRWMS M&O 2000, p. 9.2-23). Between 1985 and 1992, water use in the Amargosa Desert from this aquifer averaged 8.1 million cubic meters (6,600 acre-feet) a year for agriculture, mining, livestock, and domestic purposes (DIRS 147766-Thiel 1999, p. 15).

Table 3-11. Perennial yield and water use in the Yucca Mountain region.

Hydrographic area[a]	Perennial yield[b,c] (acre-feet per year)[d]	Current appropriations[e,c] (acre-feet per year)	Average annual withdrawals 1995-1997 (acre-feet)	Chief uses
Jackass Flats (Area 227a)	880[f] - 4,000	500[g]	340[h]	Nevada Test Site programs and site characterization of Yucca Mountain. Minor amounts of water are also discharged for tests at Yucca Mountain.
Crater Flat (Area 229)	220 - 1,000	1,200[i]	140[j]	Mining, site characterization of Yucca Mountain
Amargosa Desert (Area 230)	24,000 - 34,000	27,000	14,000[j]	Agriculture, mining, livestock, municipal, wildlife habitat
Oasis Valley (Area 228)	1,000 - 2,000	1,700	N/A[k]	Agriculture, municipal

a. A specific area in which the State of Nevada allocates and manages the groundwater resources. See Figure 3-20.
b. The quantity of groundwater that can be withdrawn annually from a groundwater reservoir, or basin, for an indefinite period of time without depleting the reservoir; also referred to as *safe yield*.
c. Sources: DIRS 147766-Thiel (1999, p. 5-12); perennial yield values only, DIRS 101811-DOE (1996, pp. 4-117 and 4-118).
d. An *acre-foot* is a commonly used hydrologic measurement of water volume equal to the amount of water that would cover an acre of ground to a depth of 1 foot. To convert acre-feet to cubic meters, multiply by 1,233.49; to convert to gallons, multiply acre-feet by 325,851.
e. The amount of water that the State of Nevada authorizes for use; the amount used might be much less. These appropriations do not cover Federal Reserve Water Rights held by the Nevada Test Site or Air Force.
f. The low estimate for perennial yield from Jackass Flats breaks the quantity down further into 300 acre-feet for the eastern third of the area and 580 acre-feet for the western two-thirds.
g. Area 227a appropriations include about 370 acre-feet for Yucca Mountain characterization activities.
h. Source of Area 227a withdrawals: DIRS 101486-Bauer et al. (1996, p. 702) and DIRS 103090-Bostic et al. (1997, p. 592) for withdrawals from wells J-12 and J-13 at the Nevada Test Site.
i. Area 229 appropriations include temporary mining rights and 61 acre-feet for Yucca Mountain characterization activities.
j. Sources of Area 229 and 230 withdrawals: DIRS 102890-La Camera, Westenburg, and Locke (1996, p. 74) and DIRS 103011-La Camera and Locke (1997, p. 77).
k. N/A = not available.

As Table 3-11 indicates, water use averaged about 17 million cubic meters (14,000 acre-feet) a year from 1995 through 1997. As listed in Table 3-11, groundwater in the Amargosa Desert is heavily appropriated—at much higher levels than is actually withdrawn.

The Ash Meadows area of the Amargosa Desert has restrictions on groundwater withdrawal as a result of a U.S. Supreme Court decision (DIRS 148102-Cappaert v. United States 1976, all) to protect the water level in Devils Hole. Devils Hole became a National Monument in 1952 to preserve the Devils Hole pupfish and the pool in which the fish live. The pool contains a rock shelf that is critical to the survival of the Devils Hole pupfish because it provides an area for the fish to feed and spawn. Withdrawal of water from the connected aquifer has caused the water level in the pool to decline. The Supreme Court found that an existing Federal water right precluded development of the aquifer to the extent that the water level in the pool be maintained at a level providing adequate coverage of the rock shelf and, thereby, providing the necessary habitat for the pupfish. The Ash Meadows National Wildlife Refuge (see Figure 3-11), which includes the Devils Hole area, was established in 1984 (see Section 3.1.5.1.3). As noted above in the discussions of basins and regional groundwater movement, groundwater flowing beneath Yucca Mountain does not contribute to the groundwater beneath the area of Ash Meadows. However, the slope of the water table from Ash Meadows to the Amargosa Desert could be affected by changes in the Desert's water table elevation.

Table 3-11 lists water volumes (*perennial yield*, appropriations, and withdrawals) in acre-feet. This unit of volume is common in hydrology and water resource planning. This EIS describes water volumes in both metric (cubic meters) and English (acre-feet) units.

Groundwater Quality. The U.S. Geological Survey has accumulated and evaluated almost 90 years of groundwater data for the Yucca Mountain region and, in more recent years, has periodically collected and analyzed groundwater quality samples (DIRS 104986-CRWMS M&O 1999, pp. 6 to 9). A recent sampling effort (DIRS 104828-Covay 1997, all) looked for a wide range of inorganic and organic constituents, as well as general water quality properties. This effort collected samples from five groundwater sources in the Amargosa Desert region and three from the immediate vicinity of Yucca Mountain (as discussed in Section 3.1.4.2.2). The regional sampling locations included two wells in the central Amargosa Desert, one well in the Ash Meadows area, and two springs along the border between the Alkali Flat-Furnace Creek and Ash Meadows groundwater basins. Selected results from the recent groundwater sampling effort are listed in Table 3-12.

Table 3-12. Concentrations of selected water quality parameters in the regional groundwater.[a,b,c]

Parameter	Range of reported concentrations (milligrams per liter)	Parameter	Range of reported concentrations (milligrams per liter)
Aluminum	0.0021 - 0.0049	Lead	<0.001 - 0.0013
Antimony	<0.001 (all)	Manganese	<0.001 - 0.0022
Arsenic	0.008 - 0.022	Mercury	<0.0001 (all)
Barium	0.0012 - 0.067	Molybdenum	0.0027 - 0.010
Beryllium	<0.001 (all)	Nickel	<0.001 (all)
Boron	0.114 - 1.06	Nitrite	<0.010 (all)
Cadmium	<0.001 (all)	Nitrite plus nitrate	<0.050 - 2.17
Chloride	6.6 - 100	Selenium	<0.001 - 0.019
Chromium	0.0022 - 0.0065	Silver	<0.001 (all)
Copper	<0.001 - 0.001	Strontium	0.041 - 1.53
Cyanide	<0.01 (all)	Sulfate	18 - 420
Fluoride	1.6 - 2.3	Thallium	<0.0005 (all)
Iron	<0.003 - 0.014	Total dissolved solids (TDS)	217 - 1,110
Organochlorine and organonitrogen compounds (analysis for 45 constituents)	None detected[d] (0.00001 - 0.001)	Zinc	<0.001 - 0.027
Volatile organic compounds (analysis for 60 constituents)	None detected[d] (0.001 - 0.006)	Semivolatile organic compounds (analysis for 57 constituents)	None detected[d] (0.003 - 0.040)

a. Source: DIRS 104828-Covay (1997, all).
b. Samples collected in May 1997 from eight locations (five in the Amargosa Desert region and three in the vicinity of Yucca Mountain).
c. Parameters selected for display are primarily those identified in EPA's Primary and Secondary Drinking Water Standards.
d. "None detected" indicates no results were above the analytical laboratory's detection limits. The range of reported detection limits is in parentheses.

The U.S. Geological Survey effort compared the regional groundwater quality measurements to the primary and secondary drinking water standards established by the Environmental Protection Agency [DIRS 104876-EPA 1993, all; see also the Safe Drinking Water Act, as amended, 42 U.S.C. 300(f) *et seq.*]. Though drinking water standards are for public water supply systems, it is common to compare results from groundwater sampling and analysis to these standards for an indication of groundwater quality. The findings indicated that the five groundwater sources met primary drinking water standards, but that a few sources exceeded secondary and proposed standards. Specifically, four of the wells exceeded a proposed standard for radon (Section 3.1.8.2 discusses the natural occurrence of radon in the Yucca Mountain region) and one of those four exceeded secondary standards for sulfate and total dissolved solids and a proposed standard for uranium. Overall, however, regional groundwater quality is generally good and consistent with the State of Nevada description that most groundwater aquifers in the State are suitable, or marginally suitable, for most uses (DIRS 148164-NDWP 1999, all). Additional water quality data for wells on the Nevada Test Site are available in the *Final Environmental Impact*

Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada (DIRS 101811-DOE 1996, pp. 4-124 to 4-126). Section 3.1.4.2.2 discusses radiological parameters, including results from regional sample locations.

3.1.4.2.2 *Groundwater at Yucca Mountain*

Groundwater at Yucca Mountain occurs in an unsaturated zone and a saturated zone. This section describes these zones and the characteristics of the groundwater in them.

SUBSURFACE FORMATIONS CONTAINING WATER

Unsaturated zone: The zone of soil or rock between the land surface and the *water table*.

Saturated zone: The region below the *water table* where rock pores and *fractures* are completely saturated with *groundwater*.

Perched water bodies: Saturated lenses (thin layers of water) surrounded by unsaturated conditions.

Unsaturated Zone

Water Occurrence. The unsaturated zone at Yucca Mountain extends down from the crest of the mountain about 750 meters (2,500 feet) to the water table (the upper surface of the saturated zone) (DIRS 151945-CRWMS M&O 2000, p. 8.1-1). The primary emplacement area (the upper block) of the proposed repository would be in the unsaturated zone, at least 160 and up to 400 meters (530 up to 1,300 feet) above the present water table (DIRS 151945-CRWMS M&O 2000, p. 9.4-1). The excavation of the Exploratory Studies Facility, including the Enhanced Characterization of the Repository Block *Cross-Drift*, involved more than 11 kilometers (8.4 miles) of tunnels and testing alcoves. Throughout this excavation, only one fracture was observed to be moist (DIRS 154565-Levich et al. 2000, p. 404); there was no active flow of water. Boreholes in the unsaturated zone identified water in the rock matrix, along faults and other fractures, and in isolated saturated zones of *perched water* (DIRS 151945-CRWMS M&O 2000, p. 8.5-1) (Figure 3-16). The water found in the pores of the rock matrix is chemically different from water found in fractures, perched water, or water in the saturated zone (DIRS 151945-CRWMS M&O 2000, pp. 8.6-1 and 8.6-2). Perched water in Yucca Mountain occurs where fractured rock overlies rock of low permeability such as unfractured rock, and upslope from faults where permeable or fractured rock lies against less permeable rock and fault fill material. Perched water bodies occur approximately 100 to 200 meters (330 to 660 feet) below the proposed repository horizon near the base of the Topopah Spring welded tuff unit (DIRS 151945-CRWMS M&O 2000, p. 8.5-10) (Figure 3-16). Water flow along fractures probably is responsible for recharging the perched water bodies. The apparent age of the perched water based on carbon-14 dating shows residence times of 3,500 to 11,000 years (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). Although there are limitations in the use of carbon-14 dating on water (such as knowing the initial activity of carbon-14, estimating sources of losses or gains, and adjusting for postnuclear age contributions), the perched water is believed to be too recent to be an accumulation of pore water from the rock matrix. Water chemistry data (discussed below) that show the perched water with different characteristics than the pore water provide additional, possibly stronger, evidence that pore water does not contribute significantly to the perched water. To learn how recently recharge might have occurred, these dating efforts also looked for the presence of tritium, which would indicate contributions from water affected by atmospheric nuclear weapons tests (after 1952). The results indicate that if tritium has reached the perched water bodies, it is in quantities too small for reliable detection (DIRS 151945-CRWMS M&O 2000, p. 5.3-30).

Hydrologic Properties of Rock. The unsaturated zone at Yucca Mountain consists of small areas of alluvium (clay, mud, sand, silt, gravel, and other detrital matter deposited by running water) and colluvium (unconsolidated slope deposits) at the surface underlain by volcanic rocks, mainly fragmented

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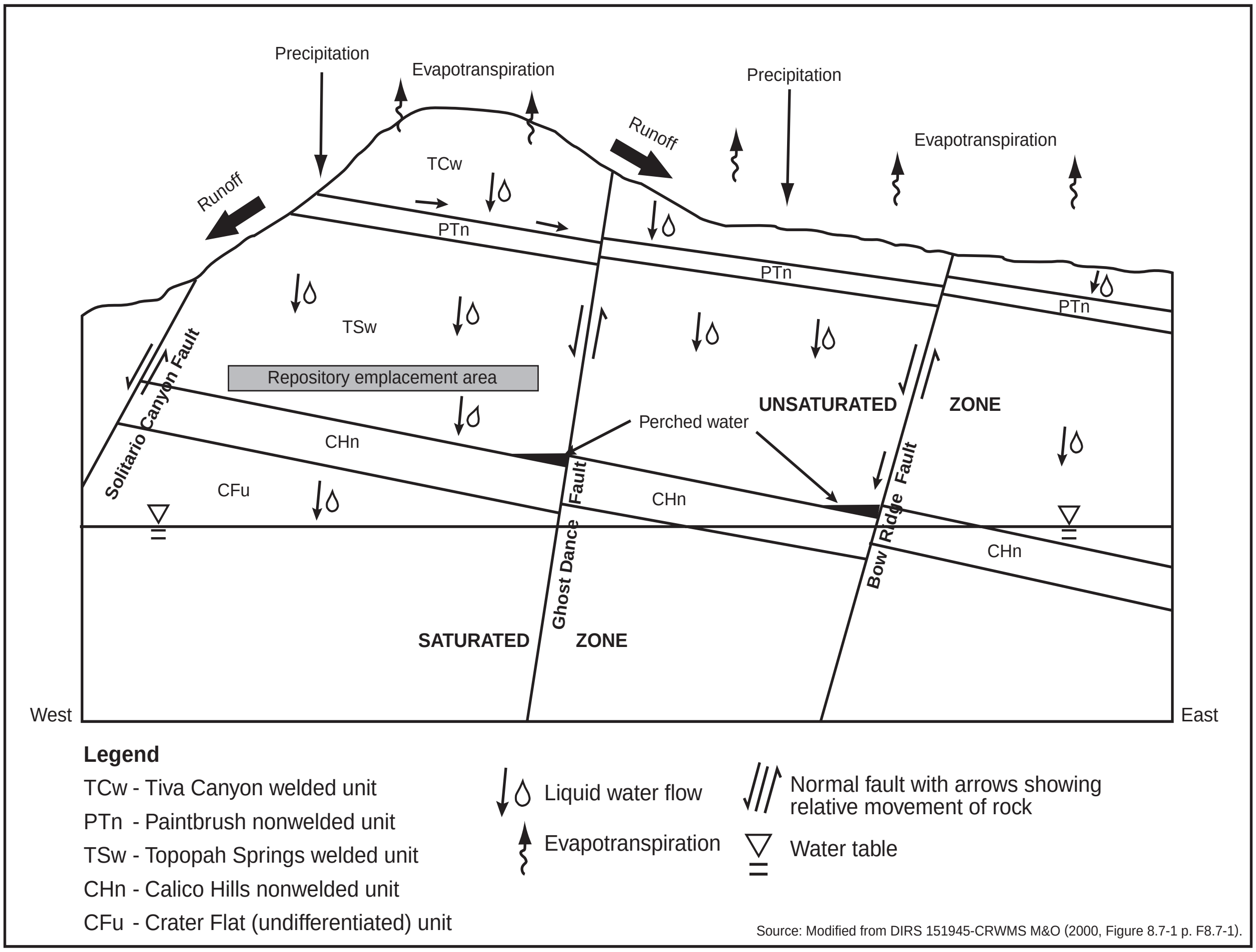


Figure 3-16. Conceptual model of water flow at Yucca Mountain.

materials called tuffs that have varying degrees of welding (DIRS 151945-CRWMS M&O 2000, p. 8.1-1). The hydrologic properties of tuffs vary widely. Some layers of tuff are welded and have low matrix porosities, but many contain fractures that allow water to flow more quickly than through the rock. Other layers, such as nonwelded and bedded tuff, have high matrix porosities but few fractures (DIRS 151945-CRWMS M&O 2000, p. 8.9-2). Some layers have many small hollow bubble-like structures (called lithophysae) that tend to reduce water flow in the unsaturated zone.

Rock units defined by a set of hydrologic properties do not necessarily correspond to rock units defined by geologic properties and characteristics. For geologic studies, rocks are generally divided on the basis of characteristics that reflect the rock origin and manner of deposition. Hydrogeologic units, on the other hand, reflect the manner in which water moves through the rock. A stratigraphic unit and a hydrogeologic unit commonly do not represent the same layer of rock. For example, a rock *stratum* classified as a single stratigraphic unit based on *lithology* or chronology, such as a tuff generated by a volcanic event, can be divided into separate hydrographic units based on hydrologic properties. Further, because the physical processes of water movement are very different under unsaturated conditions than under saturated conditions, the hydrogeologic units defined in the unsaturated zone can differ from those defined when the same rock sequence is saturated. Figure 3-17 shows the relationship between the stratigraphic units discussed in Section 3.1.3 and the hydrogeologic units discussed in this section, including the aquifers and confining units that make up the area’s groundwater system. Table 3-13 lists the hydrogeologic units in the unsaturated zone at Yucca Mountain.

Era	Geologic Age	Stratigraphic unit	Approximate range of thickness (meters)	Hydrogelogic units: Unsaturated	Hydrogelogic units: Saturated	Comments
Cenozoic Era	Quaternary and Tertiary Periods	Alluvium, colluvium, eolian deposits, spring deposits, basalt lavas, lacustrine deposits, playa deposits	**0-130**	QAL, alluvium	QTa, Valley-fill aquifer; QTc, valley-fill confining unit	QAL restricted to stream channels on Yucca Mountain; QTa occurs mainly in Amargosa Desert; major water-supply source**;** subsurface extent of the QTc unit is not well established
	Tertiary Period	Timber Mountain Group Rainier Mesa Tuff				Minor erosional remnants at Yucca Mountain
		Paintbrush Group Tiva Canyon Tuff	0-150	TCw Tiva **C**anyon welded unit		Mainly densely welded; caprock on Yucca Mountain; not known in saturated zone at or near Yucca Mountain
		(bedded tuff) Yucca Mountain Tuff Pah Canyon Tuff	20-100	PTn Paintbrush nonwelded unit		Includes bedded and nonwelded tuffs between basal part of Tiva Canyon Tuff and upper part of Topopah Spring Tuff
		Topopah Spring Tuff (vitrophyre and non-welded tuffs at base)	290-360	TSw Topopah Spring welded unit	uva, Upper volcanic aquifer	About 300 meters of densely welded tuff in unsaturated zone; host rock for repository; in saturated zone where downfaulted to east, south, and west of site
		Calico Hills Formation	150-500	CHn Calico Hills nonwelded unit	uvc, Upper volcanic confining unit	Mainly nonwelded tuff, with thin rhyolite lavas in northern site area; varies from vitric in southwest site area to zeolitic where near or below water table
		Crater Flat Group Prow Pass Tuff Bullfrog Tuff Tram Tuff	200-500	CFu Crater Flat undifferentiated unit	mva Middle volcanic aquifer	Small occurrence in unsaturated zone; widespread in saturated zone; variably welded ash-flow tuffs and rhyolite lavas; commonly zeolitized; most permeable zones are fracture-controlled
		Unnamed flow breccia Lithic Ridge Tuff	400-1,000		mvc, Middle volcanic confining unit	Nonwelded tuff, pervasively zeolitized
		Volcanics of Big Dome			lva, Lower volcanic aquifer	Lava flows and welded tuff; not known at Yucca Mountain
	(Lower Tertiary?)	Older volcanics			lvc, Lower volcanic confining unit	Nonwelded tuff, pervasively zeolitized; tuffaceous sediments in lower part
Paleozoic Era	Permian/ Pennsylvanian Periods	Bird Spring Formation Tippipah Limestone	1,000 ±		uca, Upper carbonate aquifer	Limited distribution in saturated zone north and east of Yucca Mountain
	Mississipian/ Devonian Periods	Eleana Formation (Chainman Shale)	2,500 ±		ecu, Eleana confining unit	Argillite (mudstone) and siltstone; occurrence inferred beneath volcanics of northern Yucca Mountain
	Devonian Silurian Ordovician Cambrian Periods	Devils Gate Limestone, Nevada Formation, Ely Springs Dolomite, Eureka Quartzite, Pogonip Group, Nopah Formation, Dunderberg Shale, Bonanza King Formation, Upper Carrara Formation	8,500 ±		lca, Lower carbonate aquifer	Mainly limestone and dolomite with relatively thin shales and quartzites; major regional aquifer, more than 5 kilometers (3.1 miles) thick
		Lower Carrara Formation			qcu, Precambrian confining unit	Dolomite, shale
Proterozoic (Upper Precambrian)		Proterozoic rocks				Quartzite, slate, marble; fractures commonly healed by mineralization

Source: Modified from DIRS 151945-CRWMS M&O (2000, Tables T9.3-1 and T9.3-2, Thickness date: Figures 4.5-3 and 4.5-4, pp. F4.5-3 and F4.5-4, and Table 9.2-2, pp. T9.2-2 and T9.2-3).

Figure 3-17. Correlation of generalized stratigraphy with unsaturated and saturated hydrogeologic units in the Yucca Mountain vicinity.

Table 3-13. Hydrogeologic units in the unsaturated zone at Yucca Mountain.[a]

Unit and characteristics[b]	Thickness (meters)[c]
Quaternary alluvium/colluvium Unconsolidated stream deposits beneath valleys and loose slump deposits beneath slopes; porosity and permeability medium to high.	0 - 130
Tiva Canyon welded unit (TCw) Mainly pyroclastic flow tuffs; porosity typically 10 to 30 percent; saturation commonly 40 to 90 percent.	0 - 150
Paintbrush nonwelded unit (PTn) Includes the Yucca Mountain and Pah Canyon Tuffs and uppermost part of the welded Topopah Spring Tuff; porosity generally high, 30 to 50 percent; matrix saturation, 40 to 70 percent.	20 - 100
Topopah Spring welded unit (TSw) Mainly devitrified ash flow tuff; porosity generally low, less than 20 percent, but up to 40 percent in glassy zones; matrix saturation generally greater than 50 percent, commonly greater than 80 percent.	290 - 360
Calico Hills nonwelded unit (CHn) Made up of four subunits, the lower three of which contain zeolites; the unit also includes Prow Pass Tuff (pyroclastic flow) of the Crater Flat Group; porosity generally 20 to 40 percent; matrix saturation 30 to 90 percent, commonly near 100 percent in zeolitic zones.	150 - 500
Crater Flat undifferentiated unit (CFu) Consists of welded Bullfrog Tuff (stratigraphically above) and nonwelded Tram Tuff (stratigraphically below); is below water table in much of the area, but is unsaturated beneath western part of Yucca Mountain; Bullfrog Tuff has low porosity, less than 20 percent, and high matrix saturation, close to 100 percent; Tram Tuff has porosity 20 to 40 percent; and high matrix saturation.	200 - 500

a. Source: DIRS 151945-CRWMS M&O (2000; Units and Descriptions - pp. 4.5-18 to 4.5-33 and 8.3-6 to 8.3-10; Porosity and Saturation - Figures 8.3-1 and 8.3-2, pp. F8.3-1 and F8.3-2, and Table 8.3-2, p. T8.3-3; and Thickness - Figures 4.5-3 and 4.5-4, pp. F4.5-3 and F4.5-4).
b. Letters in parentheses are used in Figures 3-16 and 3-17
c. To convert meters to feet, multiply by 3.2808.

Water Source and Movement. When precipitation falls on Yucca Mountain, part leaves as runoff, part evaporates, and part infiltrates the ground. Some of the water that infiltrates the ground eventually evaporates in the arid climate or passes to plants; the remainder percolates into the ground as infiltration.

Some of the infiltration remains at shallow levels, some eventually rises to the surface as vapor, and some (called *net infiltration*) moves deeper into the unsaturated zone. The estimated net infiltration for the current climate is 3.6 millimeters (0.1 inch) per year in a study area of about 120 square kilometers (48 square miles) that includes Yucca Mountain and 4.7 millimeters (0.2 inch) per year in the potential repository area (DIRS 151945-CRWMS M&O 2000, Tables 8.2-7 and 8.2-9, pp. T8.2-6 and T8.2-7). These are estimates of average net infiltration for fairly large surface areas. Because of the arid climate, the sporadic nature of storms, and the variation in topography, the actual amount of annual infiltration varies widely from year to year and across the area. Yucca Mountain Project studies have shown that net infiltration varies over segments of the larger areas based, in part, on the amount of unconsolidated material present. The estimated net infiltration over the study area ranges from zero where alluvium is more than 6 meters (20 feet) thick to 8 centimeters (3 inches) and more where thin alluvium overlies highly permeable bedrock (DIRS 100147-Flint, Hevesi, and Flint 1996, p. 91). On a year-to-year basis, the average net infiltration over the repository might range from 0.4 to 11.6 millimeters (0.02 to 0.5 inch) (DIRS 151945-CRWMS M&O 2000, Table 8.2-9, p. T8.2-7).

Groundwater movement in the unsaturated zone at Yucca Mountain occurs in the pore space (matrix) of rock units and along faults and fractures of rock units. Water movement through the pore space of rock units is a relatively slow (or stagnant) process compared with flow through faults and fractures (DIRS 151945-CRWMS M&O 2000, p. 8.9-10). Water movement through faults and fractures is believed to be episodic in nature (occurring at discrete times related to periods of high surface infiltration), is capable of traveling rapidly through rock units, and is the likely source of perched water in the unsaturated zone (DIRS 151945-CRWMS M&O 2000, pp. 8.9-3 to 8.9-6).

The characteristics of groundwater movement through specific rock units differ based on their hydrogeologic properties (DIRS 151945-CRWMS M&O 2000, pp. 8.9-2 to 8.9-3). Water that infiltrates into the Tiva Canyon welded unit can often be transported rapidly through fractures as deep as the underlying Paintbrush nonwelded unit. Due to its high porosity and low fracture density, the Paintbrush unit tends to slow the downward velocity of water flow dramatically in relation to highly fractured units such as the Tiva Canyon unit. However, isotopic (chlorine-36) analysis has identified isolated pathways that provide relatively rapid water movement for very small amounts of water (DIRS 151945-CRWMS M&O 2000, p. 8.12-16) through the Paintbrush nonwelded unit to the top of the underlying Topopah Springs welded unit where, due to increased fracturing, it has the potential to travel quickly through the unit.

DOE has used the ratio of chlorine-36 (a naturally occurring *isotope*) to total chlorine to determine where and when moisture has moved in the unsaturated zone at Yucca Mountain. High enough chlorine-36 ratios indicate waters exposed to very small amounts of fallout associated with above-ground nuclear weapons testing (called bomb-pulse water). The methodology used in these studies is complicated and is still under investigation; however, findings thus far have been valuable in reaching certain conclusions.

CHLORINE-36 STUDIES

These studies use the fact that a very small portion of chlorine in the atmosphere consists of the radioactive isotope chlorine-36. The production of chlorine-36 (caused in part by interactions between argon molecules and high-energy protons and neutrons in the atmosphere) is sufficiently balanced with the rate of its removal as atmospheric fallout that the ratio of chlorine-36 to stable chlorine (chlorine-35 and -37) at any given location remains fairly constant in atmospheric salts deposited on land, such as that dissolved in rainwater. Once chlorine is isolated from the surface environment (as when dissolved in water percolating down through the soil and subsurface rocks), subsequent changes in the chlorine-36-to-total-chlorine ratio can be attributed to decay of the chlorine-36 (DIRS 101005-Levy et al. 1997, p. 2) (that is, if the residence times are long enough in relation to the 301,000-year half-life of this radionuclide). Measuring the chlorine-36-to-total-chlorine ratio in underground water or in residues it leaves behind, and knowing what the ratio was at the time of recharge provides a means of estimating the age of the water. In reality, slight variations over time in the atmospheric ratio and the potential for some minor production of chlorine-36 in the subsurface has made the use of this technique for water dating difficult, and its use is still under investigation. However, the atmospheric ratio of chlorine-36 to total chlorine has increased by orders of magnitude as a result of above-ground nuclear testing during the past 50 years. As a consequence, the technique has been very successful in tracing underground water or water residues that originated at the surface within the past 50 years, with the so-called *bomb-pulse signal* indicating very young water.

Chlorine-36 analyses at Yucca Mountain have identified locations where water has moved fairly rapidly (in several decades) from the surface to the depth of the proposed repository and also where it has moved very slowly (thousands to tens of thousands of years). The chlorine-36 studies included one study that collected 247 rock samples along the 8-kilometer (5-mile) Exploratory Studies Facility tunnel (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). About 70 percent of the samples were from areas thought to be more likely to show evidence of rapid water movement [that is, areas of broken rock such as faults, fractures, or breccia zones (areas where rock composed of fragments of older rocks melded together)] (DIRS 100144-Fabryka-Martin et al. 1997, p. 4-13).

Most of the samples (77 percent) had ratios that were ambiguous in that they fell within the range over which the chlorine-36-to-total-chlorine ratio has varied over the last 30,000 years or more (DIRS 100144-Fabryka-Martin et al. 1997, p. 3-1). Results of these samples indicate that the groundwater travel times from the surface to the repository depth in most areas probably are thousands to tens of thousands of years. This is because there is little evidence for measurable radioactive decay of the chlorine-36 signal in the subsurface. However, a few samples indicated ratios low enough to suggest the possible presence of zones of relatively old or stagnant water.

About 13 percent of the samples (31 samples) had high enough chlorine-36-to-total-chlorine ratios to indicate the water originated from precipitation occurring in the past 50 years (that is, nuclear age precipitation) (DIRS 151945-CRWMS M&O 2000, p. 8.6-3). Locations where bomb-pulse water occurred were correlated with the physical conditions in the mountain and on the surface that could lead to, or otherwise affect, the findings. The conclusion to date of these ongoing studies is that relatively fast transport of water through the mountain is controlled by the following factors (DIRS 104878-CRWMS M&O 1998, p. 3-2):

- The presence of a continuous fracture path from the surface: The limiting factor is a fracture or fault cutting the Paintbrush nonwelded bedded tuffs (PTn) hydrogeologic unit (this prominent unit is above the repository horizon; see Figure 3-16 and Table 3-13). Fracture pathways are normally available in the welded portions of the overlying Tiva Canyon and underlying Topopah Spring units. This is consistent with hydrologic modeling of *percolation* through this nonwelded bedded tuff, which indicates that there must be fracture pathways due to faulting or other disturbances for water to travel through this unit in 50 years or less. Section 3.1.3 discusses fault locations inside Yucca Mountain.

- The magnitude of surface infiltration: There must be enough infiltration to sustain a small component of flow along the connected fracture pathway.

- The residence time of water in the soil cover: This time must be less than 50 years; to achieve this, the depth of the soil overlying the fracture pathway must be less than an estimated 3 meters (10 feet).

Several important factors affect a discussion of chlorine-36 studies. Ratios of naturally occurring radioactive chlorine-36 to the other isotopes of chlorine are on the order of one chlorine-36 atom to approximately two trillion (2,000,000,000,000) other chlorine atoms. Samples designated as showing evidence of elevated, "bomb-pulse" chlorine-36 still have exceedingly minute amounts of this isotope, containing only two to eight times the amount that occurs naturally. The scale of these measurements and the significance being placed on them makes understanding the sources of chlorine-36 in the underground environment and the intricacies of the analytical procedures extremely important. To ensure the correct interpretation of this subtle chemical signal (that is, of elevated amounts of chlorine-36), studies are underway to determine whether independent laboratories and related isotopic studies corroborate the findings.

Water percolating to the depth of the repository and beyond is affected not only by fractures but also by the nature of the hydrogeologic units it encounters. Pressure testing in boreholes indicates that fractures in the Topopah Spring tuff (the rock unit in which DOE would build the repository) are very permeable and extensively interconnected (DIRS 151945-CRWMS M&O 2000, p. 8.12-5). Below the repository level, low-permeability zones impede the vertical flow of water in the Calico Hills nonwelded unit (which includes the basal part of the Topopah Springs Tuff, Figure 3-17), forming perched water bodies (DIRS 151945-CRWMS M&O 2000, pp. 8.9-5 and 8.9-6). The primary source of the perched water is water traveling down along faults and fractures. In the dipping or sloped strata beneath Yucca Mountain, perched water bodies require vertical impediments such as fault zones where less permeable rock and fault-gouge material block the lateral flow of water (Figure 3-16). If these conditions do not exist at the fault zone, the fault can provide a downward pathway. Even in cases where fault zones are barriers to lateral water flow, they can be very permeable to gas and moisture flow along the fault plane and permit the rapid vertical flow of water from the land surface to great depth. Studies of heat flux above and below the perched water zone appear to indicate more water percolation above the perched water than below (DIRS 100627-Bodvarsson and Bandurraga 1996, p. 21). This is consistent with the concept that some of the water moves laterally on top of the low-permeability zone before it resumes its downward course to the saturated zone.

DOE has recently undertaken development of what is termed an "expected-case" model of groundwater flow in the unsaturated zone as reported in DIRS 156609-BSC (2001, all). One of the objectives of this effort was to evaluate the impact of the conservatism in the Total System Performance Assessment (TSPA) modeling (see Chapter 5 and Appendix I). The study examined the flow and transport models used in the TSPA effort to identify areas where conservatism could be reduced and uncertainty better characterized. The result is a model of unsaturated zone flow that DOE believes is more realistic than the conservative one. The expected-case model was run under several varying conditions, including runs assuming a nonsorbing tracer, which moves like water, was released at the level of the proposed repository. The results indicate it would take in the range of 7,000 to 8,000 years for 50 percent of the tracer to reach the underlying water table (DIRS 156609-BSC 2001, Figure 6.5-29, p. 183). Some of the tracer would find its way to faster pathways to the water table; some would take longer to travel the distance. Several different conceptual models of groundwater movement in the unsaturated zone were integrated into runs of the numerical mode. DOE believes the most likely case, as described here, presents an estimate of groundwater travel time from the proposed repository to the water table that is a reasonable representation of what occurs in the natural setting.

Unsaturated Zone Groundwater Quality. DOE has analyzed water from the unsaturated zone, both pore water from the rock matrix and perched water, to obtain information on the mechanisms of recharge and the amount of connection between the two. The preceding sections discuss some of the relevant findings.

Table 3-14 summarizes the chemical composition of perched and pore water samples from the vicinity of Yucca Mountain.

Table 3-14. Water chemistry of perched and pore water samples in the vicinity of Yucca Mountain.[a]

	Ranges of chemical composition	
Constituent	Perched	Pore
pH	7.6 - 8.7	7.7 - 8.4
Total dissolved solids (milligrams per liter)	140 - 330	320 - 360
Calcium (milligrams per liter)	2.9 - 45	1.1 - 62
Magnesium (milligrams per liter)	0 - 4.1	0 - 4.5
Potassium (milligrams per liter)	1.7 - 10	N/A[b]
Sodium (milligrams per liter)	34 - 98	49 - 140
Bicarbonate (milligrams per liter)	110 - 220	170 - 230
Chloride (milligrams per liter)	4.1 - 16	26 - 90
Bromide (milligrams per liter)	0 - 0.41	0
Nitrate (milligrams per liter)	0 - 34	11 - 17
Sulfate (milligrams per liter)	4 - 220	14 - 45

a. Source: DIRS 104951-Striffler et al. (1996, Table 2).
b. N/A = not available.

The smaller concentrations of dissolved minerals, particularly chloride, in perched water in comparison to those in pore water is a primary indicator of differences between the two. This difference in dissolved mineral concentrations indicates that the two types of water do not interact to a large extent and that the perched water reached its current depth with little interaction with rock. This, in turn, provides strong evidence that flow through faults and fractures is the primary source of the perched water (DIRS 151945-CRWMS M&O 2000, p. 5.4-2).

Saturated Zone

Water Occurrence. The saturated zone at Yucca Mountain has three aquifers and two confining units. The aquifers are commonly referred to as the upper volcanic aquifer, the lower volcanic aquifer, and the lower carbonate aquifer. The interlayered aquitards (low permeability units that retard water movement) that separate the aquifers are called the upper volcanic confining unit and the lower volcanic confining unit (see Figure 3-17). The upper volcanic aquifer is composed of the Topopah Spring welded tuff, which occurs in the unsaturated zone near the repository but is present beneath the water table to the east and south of the proposed repository. The upper volcanic confining unit includes the vitrophyre and nonwelded tuffs at the base of the Topopah Spring Tuff, the Calico Hills nonwelded unit, and the uppermost unstructured end of the Prow Pass tuff where they are saturated. The lower volcanic aquifer includes most of the Crater Flat Group, and the lower volcanic confining unit includes the lowermost Crater Flat Group and deeper tuff, lavas, and flow breccias. An upper carbonate aquifer, though regionally important, is not known to occur beneath Yucca Mountain. (The lower volcanic aquifer discussed here corresponds to the middle volcanic aquifer shown in Figure 3-17. The lower volcanic aquifer in Figure 3-17 has not been identified in the area of the proposed repository.)

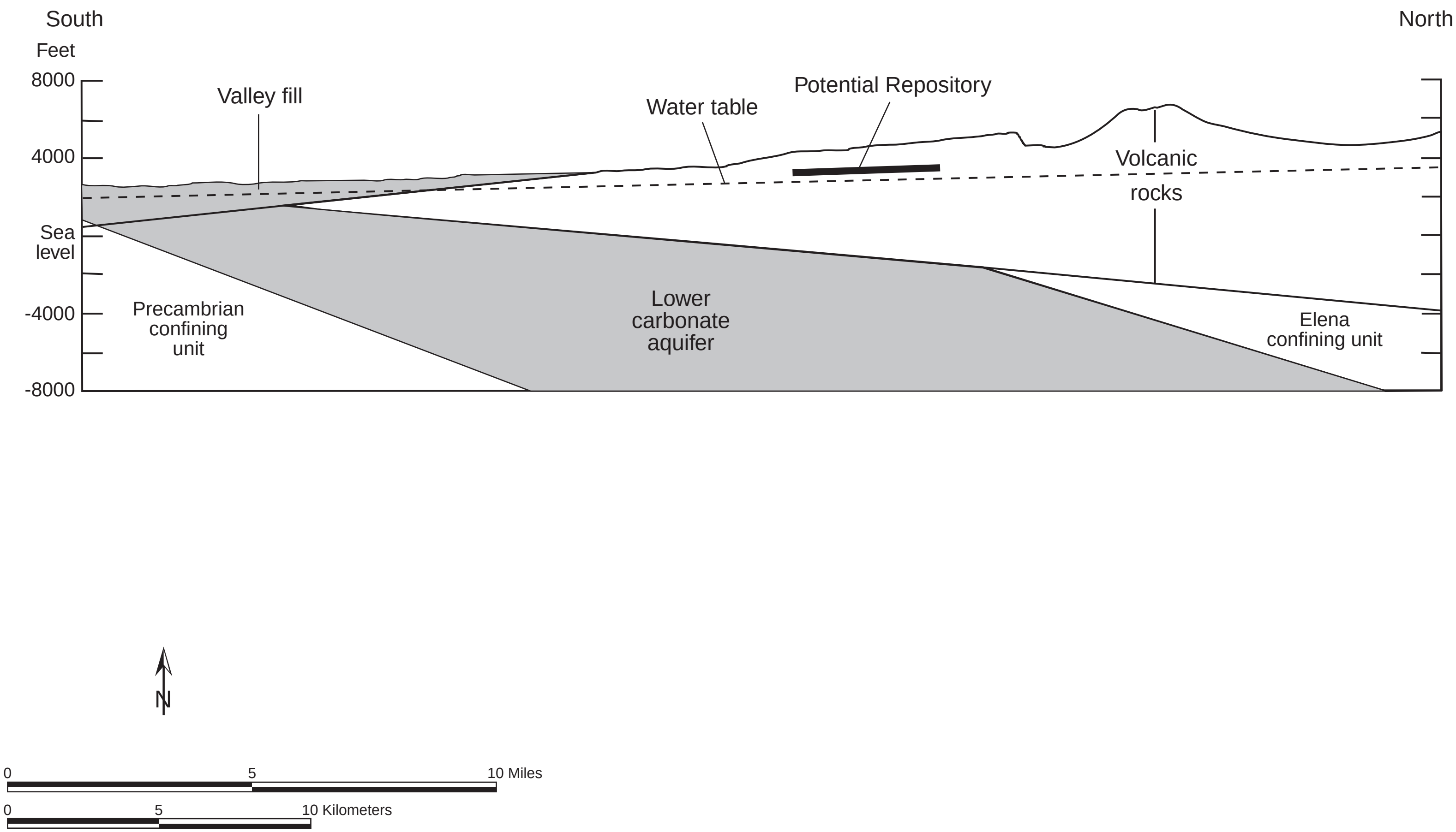
TYPES OF TUFF

Welded tuff results when the volcanic ash is hot enough to melt together and is further compressed by the weight of overlying materials.

Non-welded tuff results when volcanic ash cools in the air sufficiently that it does not melt together, yet later becomes rock through compression.

South of the proposed repository site, downgradient in the groundwater flow path from Yucca Mountain, the Tertiary volcanic rocks (and the volcanic aquifers) pinch out and groundwater moves into the valley-fill sediments of the Amargosa Desert (DIRS 151945-CRWMS M&O 2000, p. 9.3-80). Figure 3-18, which is a generalized hydrogeologic cross-section from Yucca Mountain to the northern portion of the Amargosa Desert, shows the relative positions of these aquifers. In the Amargosa Desert south of Yucca Mountain, the most important source of water is an aquifer formed by valley-fill deposits (DIRS 151945-CRWMS M&O 2000, p. 9.2-23).

The lower carbonate aquifer is more than 1,250 meters (4,100 feet) below the proposed repository horizon (DIRS 151945-CRWMS M&O 2000, Table 9.3-8, p. T9.3-10). This aquifer, which consists of lower Paleozoic carbonate rocks (limestone and dolomite) that have been extensively fractured during many periods of mountain building (see Section 3.1.3), forms a regionally extensive aquifer system through which large amounts of groundwater flow (DIRS 151945-CRWMS M&O 2000, p. 9.2-8). Evidence indicates that water in the lower carbonate aquifer is at least as old as most of the water in the volcanic aquifers (with apparent ages in the range of 10,000 to 20,000 years) (DIRS 151945-CRWMS M&O 2000, pp. 9.2-57 and 9.6-4) and, similarly, was recharged during a wetter and cooler climate (DIRS 151945-CRWMS M&O 2000, p. 9.6-4). Some of the limited carbonate aquifer sample results indicate older water ages (up to 30,000 years), but use of carbon-14 dating on this water has an additional limitation due to the probable contribution of "dead carbon" (nonradioactive) dissolved from the carbonate rock (DIRS 151945-CRWMS M&O 2000, p. 9.2-57).



Source: Modified from DIRS 151945-CRWMS M&O (2000, Figure 9.3-4, p. F9.3-4).

Figure 3-18. Cross section from Northern Yucca Mountain to Northern Amargosa Desert, showing generalized geology and the water table.

Limited data at Yucca Mountain show that the level to which water rises in a well that penetrates the lower carbonate aquifer is about 20 meters (66 feet) higher than the water levels in the overlying volcanic aquifers (DIRS 151945-CRWMS M&O 2000, p. 9.3-34). Four other wells at Yucca Mountain that penetrate as deep as the lower volcanic confining unit (the unit above the carbonate aquifer), show higher potentiometric levels in that unit than in overlying volcanic aquifers. This might be an indication of the upward hydraulic gradient in the carbonate aquifer (DIRS 100465-Luckey et al. 1996, p. 29). One of the wells for the Nye County Early Warning Drilling Program, which is about 19 kilometers (12 miles) south of the repository site, also penetrated the carbonate aquifer and shows it to have an upward gradient. At this location, water in the carbonate aquifer well rises 8 meters (26 feet) higher than the water level in the overlying volcanic aquifer (DIRS 155950-BSC 2001, pp. 12-12 and 12-13, and Figure 12.3.2-1, p. 12F-4). This indicates that, in the vicinity of Yucca Mountain, and in areas to the south, water from the lower carbonate aquifer is pushing up against a confining layer with more force than the water in the upper aquifers is pushing down. This suggests that water in the volcanic aquifers does not flow down into the lower carbonate aquifer at Yucca Mountain because it would be moving against a higher upward pressure and that, if mixing occurs, it would be from carbonate to volcanic and not the reverse.

Paleoclimatic (referring to the climate during a former period of geologic time) studies have identified five wetter and cooler periods in the southern Great Basin during the past 400,000 years (late Pleistocene). These periods occurred 10,000 to 50,000 years ago; 60,000 to 70,000 years ago; 120,000 to 170,000 years ago; 220,000 to 250,000 years ago; and 330,000 to 400,000 years ago. They represent the sequencing of glacial (cooler and wetter) to interglacial (warmer and drier) and back to glacial climates (DIRS 151945-CRWMS M&O 2000, p. 6.3-19). Calcite veins and opal were deposited along fractures during the wetter periods. The calcite and opal coatings have been dated by the uranium series method; the calcites have also been dated by the carbon-14 method. The youngest vein deposits are 16,000 years old (DIRS 151945-CRWMS M&O 2000, p. 6.3-33). During the wetter periods, the estimated regional water table was a maximum of 120 meters (390 feet) above the present level beneath Yucca Mountain during the past million or more years based on mineralogic, isotopic, and discharge deposit data and on hydrologic modeling analysis. The water table could rise by an estimated 50 to 130 meters (160 to 430 feet) from current levels under hypothetical future wetter climate conditions (DIRS 137917-CRWMS M&O 2000, p. 9.4-24). The proposed repository drift layouts would all be well above these historic and possible future maximum water table elevations (see Section 2.1). The *Yucca Mountain Site Description* (DIRS 151945-CRWMS M&O 2000, pp. 6.3-1 to 6.3-39) provides additional information, including supporting evidence, on the timing, magnitude, and character of past climate changes in the Yucca Mountain region.

Several investigators have suggested that the water table in the vicinity of Yucca Mountain has risen dramatically higher than 120 meters (390 feet) above the current level, even reaching the land surface in the past (DIRS 106963-Szymanski 1989, all). If such an event occurred, it would affect the performance of the proposed repository. These concerns originated in the early- to mid-1980s when surface excavations performed as part of site investigations exposed vein-like deposits of calcium carbonate and opaline silica (DIRS 151945-CRWMS M&O 2000, p. 4.4-25). DIRS 106963-Szymanski (1989, all) hypothesized that the carbonate and silica were deposited by hydrothermal fluids, driven to the surface by pressurization of groundwater by earthquakes (a mechanism called *seismic pumping*) or by thermal processes that occurred in the Yucca Mountain vicinity. A number of investigators and groups, including a National Academy of Science panel specifically designated to look at the issue (DIRS 105162-National Research Council 1992, all), have examined the model on which this position is based and have rejected its important aspects (DIRS 100465-Luckey et al. 1996, pp. 76 to 77). The National Research Council panel concluded that the evidence cited as proof of groundwater upwelling in Yucca Mountain and in its vicinity could not reasonably be attributed to that process. In addition, the panel stated its position that the proposed mechanism for upwelling water was inadequate to raise the water table more than a few tens of meters (DIRS 101779-DOE 1998, Volume 1, p. 2-26). Finally, the panel concluded that the carbonate-rich depositions in fractures were formed from surface water from precipitation and surface processes (DIRS 151945-CRWMS M&O 2000, p. 4.4-36).

Another alternative interpretation of past groundwater levels at Yucca Mountain occurs in DIRS 104875-Dublyansky (1998, all). This study involved the examination of tiny pockets of water (known as *fluid inclusions*) trapped in the carbonate-opal veinlets deposited in rock fractures at Yucca Mountain. According to the report, an analysis of samples collected from the Exploratory Studies Facility includes evidence of trace quantities of hydrocarbons and evidence that the fluid inclusions were formed at elevated temperatures. These findings, and others, are used to support the report's conclusion that the carbonate-opal veinlets were caused by warm upwelling water and not by the percolation of surface water. DOE, given the opportunity to review a preliminary version of the report, arranged for review by a group of independent experts, including U.S. Geological Survey personnel and a university expert. This review group did not concur with the conclusion in the report by DIRS 104875-Dublyansky (1998, all), which now contains an appendix with the DOE-arranged review comments and the author's responses. Although DOE disagreed with some of the central scientific conclusions presented in this report, both parties agreed that additional research was needed to resolve the issue. As a result, DOE supported an independent investigation by the University of Nevada at Las Vegas, in which both the U.S. Geological Survey and the State of Nevada were invited to participate. This independent effort to analyze mineral samples from Yucca Mountain is not yet final, but University researchers presented papers on their preliminary findings at a November 2000 meeting of the Geological Society of America. They reported (DIRS 154280-Wilson et al. 2000, all) that evidence was present of fluid inclusions being formed at elevated temperature, but generally in the older (basal) part of the samples. Uranium-lead dating of the minerals in the younger outer surfaces, where there was no such evidence, indicates these minerals began precipitating between 3.8 and 1.9 million years ago. As a result, the study concluded that passage of fluids with elevated temperatures occurred prior to that time.

Opposing viewpoints dealing with the analysis of mineral samples from Yucca Mountain were presented at the same meeting of the Geological Society of America. One paper (DIRS 154790-Pashenko and Dublyansky 2000, all) reiterated the position that the apparent deposition temperatures of fluid inclusions were simply too high to be attributed to descending rainwater. Another (DIRS 154789-Dublyansky 2000, all) pointed to the diversity in the make-up of the mineral deposits as another piece of evidence suggesting a low-temperature hydrothermal (upwelling) origin. DOE and the State of Nevada are continuing to evaluate these and other alternative conceptual models and data interpretations.

Hydrologic Properties of Rock. This section discusses the hydrologic properties of rock in the saturated zone, and specifically the aquifers and confining units at Yucca Mountain. As discussed above, these properties depend in part on whether the rocks are saturated. In general, the amount and speed at which water flows through an aquifer depend chiefly on the transmissivity and effective porosity of the rock. *Transmissivity* is a measure of how much water an aquifer can transfer and is equal to the average hydraulic conductivity of the aquifer multiplied by the thickness of the aquifer that is saturated. *Hydraulic conductivity* is the volume of water moving in an aquifer during a unit of time through a unit of area that is perpendicular to the direction of flow. *Porosity* is the ratio of the rock's void (open) space to its total volume; *effective porosity* is the ratio of interconnected void space to total volume.

Figure 3-19 shows the types of conditions that might exist in gravel and rock aquifers that would make them more or less permeable to water movement. The empty spaces between gravel fragments or in the rock fractures represent the porosity. Although not necessarily representative of conditions at Yucca Mountain, the figure shows that the manner in which void spaces are interconnected, more than their size or quantity, determines how water can move through the material. At Yucca Mountain, conditions are often such that the rock with the highest porosity is also the rock with the fewest fractures (DIRS 151945-CRWMS M&O 2000, p. 9.2-7). Because the void spaces are not interconnected very well, such a high-porosity rock has low transmissivity. Because a large portion of the groundwater flow at Yucca Mountain

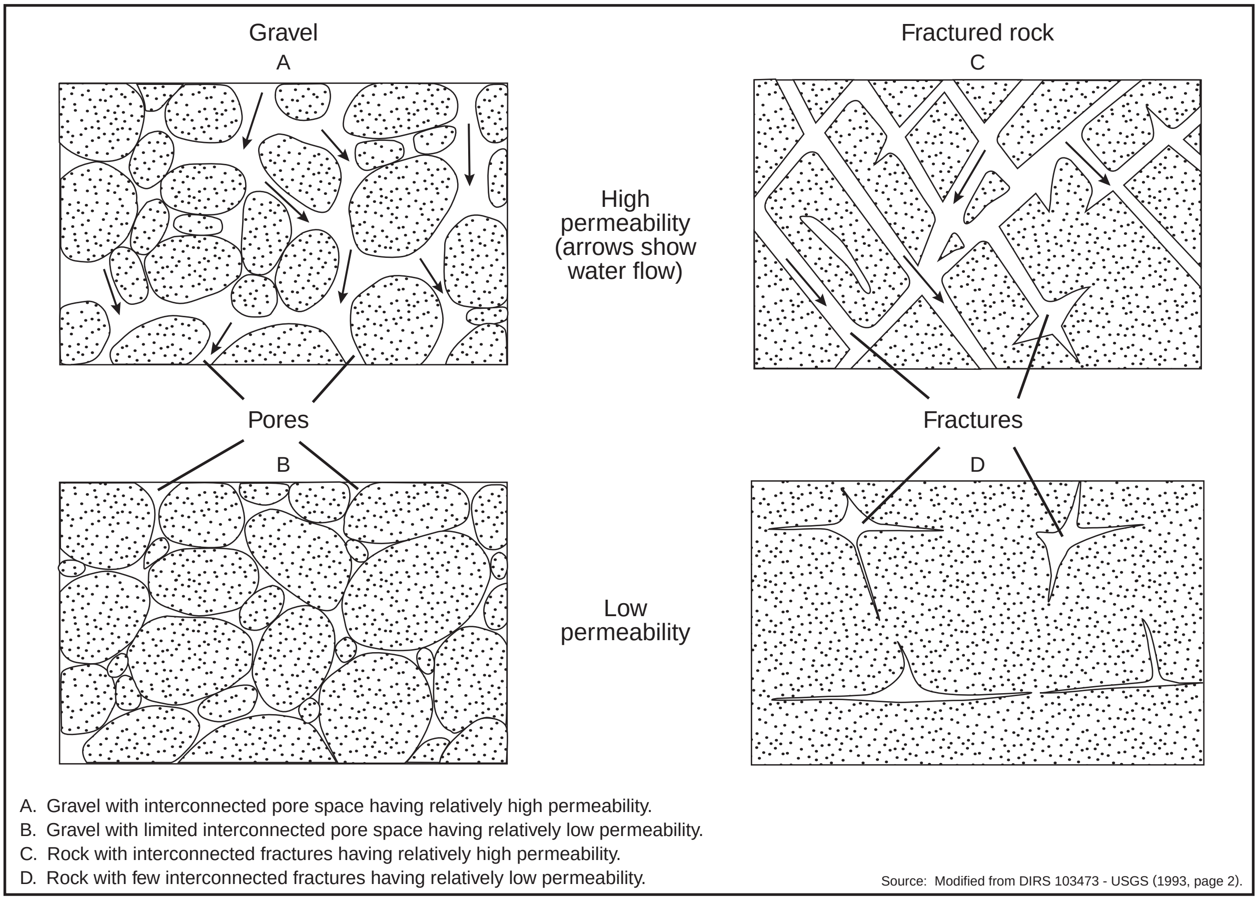


Figure 3-19. Aquifer porosity and effects on permeability.

is probably along fractures, representative transmissivity values are difficult to measure. Measurements can vary greatly depending on the nature of the fractures that happen to be intercepted by the borehole and the location in the borehole at which measurements are made. This is reflected in the wide range of transmissivity values listed in Table 3-15, which also lists the characteristics, thicknesses, apparent hydraulic conductivities, and porosities of the three aquifers and two confining units beneath Yucca Mountain. For the lower carbonate aquifer, the table lists a single transmissivity value because there was only a single test for that unit. Similarly, only one apparent hydraulic conductivity value, which is a measure of the aquifer's capacity to transport water, is provided for the lower carbonate aquifer unit because it is based on tests in a single well at Yucca Mountain. However, the value is an average of measurements taken from that well. This and the other hydraulic conductivity values are called *apparent* because they are all based on single-borehole tests. Such measurements, which are believed to represent conditions at a limited distance around the well, could vary greatly depending on whether there are water-bearing fractures in the well zone being tested. When such fractures are present, hydraulic properties measured in a single-borehole test probably reflect conditions only in isolated locations rather than in the overall rock matrix in the test zone.

Water Source and Movement. Section 3.1.4.2.1 describes the direction of water movement (Figure 3-15), the nature of the rock through which it moves, and where local recharges to and discharges from the aquifer might occur.

When undisturbed by pumping, groundwater levels at Yucca Mountain have been very stable. A Geological Survey study of water levels over 10 years (1985 to 1995) indicated water levels did not change by season and most water-level fluctuations are probably due to changes in barometric pressure

Table 3-15. Aquifers and confining units in the saturated zone at Yucca Mountain.

Unit	Typical thickness (meters)[a,b,c]	Transmissivity (square meters per day)[d,e]	Apparent hydraulic conductivity (meters per day)[e]	Typical porosity[f,g] (ratio)
Upper volcanic aquifer Densely welded and densely fractured part of Topopah Spring Tuff	300	120 - 1,600	0.13 - 19	0.05 - 0.10
Upper volcanic confining unit Basal vitrophyre of Topopah Spring Tuff, Calico Hills Formation Tuff, and uppermost nonwelded part of Prow Pass Tuff	90 - 330	2.0 - 26	0.02 - 0.26	0.l9 - 0.28
Lower volcanic aquifer Most of Prow Pass Tuff and underlying Bullfrog and Tram Tuffs of Crater Flat Group	370 - 700	1.1 - 3,200	< 0.0037 - 13	0.19 - 0.24
Lower volcanic confining unit Bedded tuffs, lava flows, and flow breccia beneath Tram Tuff	370 - > 750	0.003 - 23	5.5×10^{-6} - 0.11	0.15 - 0.24
Lower carbonate aquifer Cambrian through Devonian limestone and dolomite	N/A[h]	120	0.19	0.003 - 0.05

a. Source: DIRS 100465-Luckey et al. (1996, Table 2 and Figure 7).
b. To convert meters to feet, multiply by 3.2808.
c. Typical thickness ranges for the upper volcanic confining unit, the lower volcanic aquifer, and the lower volcanic confining unit are based on measurements from 13 boreholes. With respect to the lower volcanic confining unit, only one penetrated and showed a unit thickness of about 370 meters (1,200 feet); of the others, about 750 meters (2,500 feet) was the deepest penetration without passing through. Water was detected in the rock unit that elsewhere makes up the upper volcanic aquifer unit in only one of the 13 boreholes. (Beneath the center of Yucca Mountain, the upper volcanic aquifer is above the saturated zone.) The typical thickness shown here for this unit is based on Figure 7 from DIRS 100465-Luckey et al. (1996, Figure 7).
d. To convert square meters to square feet, multiply by 10.764.
e. Source: DIRS 151945-CRWMS M&O (2000, Tables 9.3-4 and 9.3-5, pp. T9.3-6 and T9.3-7).
f. Source: DIRS 151945-CRWMS M&O (2000, pp. 9.3-10 to 9.3-17).
g. Ranges are for means of several hydrogeological subunits.
h. N/A = not available.

and Earth tides (DIRS 151945-CRWMS M&O 2000, p. 9.3-30). In addition, short-term fluctuations in groundwater elevations also have been attributed to apparent recharge events and earthquakes. Water levels in wells have fluctuated by as much as 0.9 meter (3 feet) in response to earthquake events, and confined water pressure deep in wells fluctuated by as much as 2.2 meters (7 feet) in response to those same events. However, the fluctuations are typically of short duration with water levels returning to the pre-earthquake conditions within minutes to a few hours (DIRS 151945-CRWMS M&O 2000, pp. 9.4-20 and 9.4-21). An exception to this occurred in response to earthquakes in the summer of 1992, when water levels in specific wells at Yucca Mountain fluctuated over several months.

At the northern end of Yucca Mountain, the apparent potentiometric surface slopes steeply southward, dropping almost 300 meters (980 feet) in a horizontal distance of about 2 kilometers (1.2 miles) (DIRS 151945-CRWMS M&O 2000, pp. 9.2-46 and 9.3-31). Experts reviewing the data have suggested several credible reasons for this large gradient, including that it results from an undetected geological feature with low permeability, that it is caused by groundwater draining to deep aquifers, or that it is a perched water table being encountered in this area (DIRS 100353-CRWMS M&O 1998, pp. 3-5 and 3-6). However, there are no obvious geologic reasons for the large gradient, and it is still under investigation.

The north-trending Solitario Canyon fault, on the west side of Yucca Mountain, apparently impedes the eastward flow of groundwater in the saturated zone. West of the fault, the water table slopes moderately about 40 meters (130 feet) in less than 1 kilometer (0.6 mile), while east of the fault the water table slopes very gently, changing by only 0.1 to 0.3 meter per kilometer (0.5 to 1.6 feet per mile) (DIRS 151945-CRWMS M&O 2000, pp. 9.3-38 to 9.3-40, and Figure 9.3-15, p. F9.3-15). West of the Solitario Canyon fault groundwater probably flows southward either along the fault or beneath Crater Flat.

The gentle southeastward groundwater gradient east of the Solitario Canyon fault underlies the proposed repository horizon and extends beneath Fortymile Wash and probably farther east into Jackass Flats. This gentle gradient might indicate that the rocks through which the water flows are highly transmissive, that only small amounts of groundwater flow through this part of the system, or a combination of both. This gentle southeastward gradient is a local condition in the regional southward flow of the groundwater.

In an opposing viewpoint about the stability of groundwater levels at Yucca Mountain, DIRS 103180-Davies and Archambeau (1997, pp. 33 and 34) suggests that a moderate magnitude earthquake at the site could cause a southward displacement of the large hydraulic gradient to the north of the proposed repository, resulting in a water table rise of about 150 meters (490 feet) at the site. In addition, that report proposed that a severe earthquake could cause a rise of about 240 meters (790 feet) in the water table, flooding the repository. As part of its study of groundwater flow in the saturated zone, DOE elicited expert opinions on various issues from a panel of five experts in the fields of groundwater occurrence and flow. Among the issues put to the panel were those raised by DIRS 103180-Davies and Archambeau (1997, all). The panel reviewed the Davies and Archambeau paper and received briefings by project personnel and outside specialists. The consensus of the panel was that a rise of the groundwater to the level of the proposed repository was essentially improbable and that changes to the water table associated with earthquakes would be neither large nor long-lived (DIRS 100353-CRWMS M&O 1998, p. 3-14).

Inflow to Volcanic Aquifers at Yucca Mountain. There are four potential sources of inflow to the volcanic aquifers in the vicinity of Yucca Mountain: (1) lateral flow from volcanic aquifers north of Yucca Mountain, (2) recharge along Fortymile Wash from occasional stream flow, (3) precipitation at Yucca Mountain, and (4) upward flow from the underlying carbonate aquifer. The actual and relative amounts of inflow from each source cannot be measured directly on any large-scale basis. However, estimates have been generated based on data collected and tests performed at individual locations and from incorporation of these data into regional- and site-scale models of the unsaturated and saturated zones.

North of Yucca Mountain, the potentiometric surface rises steeply toward probable recharge areas on Pahute Mesa (Figure 3-15) and Rainier Mesa. Chemical data indicate that some recharge to the groundwater has occurred everywhere in the Yucca Mountain vicinity during the past 10,000 years, but that most recharge occurred between 10,000 and 20,000 years ago (based on apparent carbon-14 ages) during a wetter climate (DIRS 151945-CRWMS M&O 2000, p. 9.3-53). From west to east across Yucca Mountain, the age of water in the saturated zone decreases from about 19,000 years to 9,100 years (DIRS 101036-Benson and McKinley 1985, p. 4).

One estimate of the annual recharge along a 42-kilometer (26-mile) segment of Fortymile Wash in the area of Yucca Mountain is about 110,000 cubic meters (88 acre-feet) (DIRS 151945-CRWMS M&O 2000, pp. 7.2-1 and 7.2-2). Much of the recharge occurs during and after heavy precipitation when water flows in the wash. On rare occasions, Fortymile Wash carries water to Jackass Flats and into the Amargosa Desert. After periods of flow in Fortymile Wash during 1983, 1992, 1993, and 1995 water levels in nearby wells rose as a result of infiltration (DIRS 151945-CRWMS M&O 2000, p. 7.2-2). Earlier studies found that shallow water in some wells was younger than water deeper in the wells, indicating that recharge was occurring (DIRS 151945-CRWMS M&O 2000, p. 9.3-53). Paleoclimatic evidence suggests that perennial water was present in Fortymile Wash 50,000 years ago (DIRS 105162-National Research Council 1992, Appendix C, p. 198), and that substantial recharge might have occurred as recently as 7,000 to 15,000 years ago (DIRS 151945-CRWMS M&O 2000, p. 9.3-53).

Recharge to the saturated zone below Yucca Mountain from precipitation is small in comparison to inflow from volcanic aquifers to the north or recharge along Fortymile Wash (see the unsaturated zone discussion). An average net infiltration of 4.7 millimeters (0.2 inch) over a 4.7-square-kilometer (1.8-square-mile) repository footprint would produce a quantity of recharge about 20 percent of the estimated annual recharge along the nearby 42-kilometer (26-mile) segment of Fortymile Wash.

Monitoring well data collected during the site characterization effort have shown that the potentiometric surface of the carbonate aquifer (that is, the level to which water rises in wells tapping this aquifer), at least in the immediate vicinity of Yucca Mountain, is higher than the water level in the overlying volcanic aquifer. Based on this and other considerations, studies suggest that, provided structural pathways exist, the lower carbonate aquifer might provide upward flow to the volcanic aquifer beneath the proposed level of the repository and farther south. The amount of inflow, if it occurs, is not known.

Outflow from Volcanic Aquifers at and Near Yucca Mountain. Pathways by which water might leave the volcanic aquifers in the Yucca Mountain vicinity include (1) downgradient movement into other volcanic aquifers and alluvium in the Amargosa Desert, (2) downward movement into the carbonate aquifer (though evidence indicates that this does not occur), and (3) upward movement into the unsaturated zone. In addition, water is pumped from wells for a variety of uses, as described in Section 3.1.4.2.1. With the exception of well withdrawals, the actual and relative amounts of outflow from each source are not known.

The regional slope of the potentiometric surface indicates that much of the groundwater flowing southward beneath Yucca Mountain discharges about 60 kilometers (37 miles) to the south at Alkali Flat (Franklin Lake Playa) and in Death Valley. Death Valley, more than 80 meters (260 feet) below sea level, is the final sink for surface water and groundwater in the Death Valley regional groundwater flow system (Figure 3-13); as such, water leaves only by evapotranspiration. Therefore, the pathway for groundwater beneath Yucca Mountain, as indicated by the potentiometric surface, is southerly where it traverses portions of the volcanic aquifers before encountering the basin-fill alluvium and carbonate rock that underlie the Amargosa Desert.

Outflow from the volcanic aquifers into the underlying carbonate aquifer might occur, but direct evidence for this does not exist. Studies suggest that the steeply sloping potentiometric surface at the north end of Yucca Mountain could be explained by a large outflow from the volcanic aquifers to the carbonate aquifer. However, in the vicinity of Yucca Mountain, data available on the potentiometric head of the carbonate aquifer indicate that the opposite condition (that is, outflow from the carbonate aquifer up to the volcanic aquifer) is more likely.

The third possible pathway of outflow from the volcanic aquifer (that is, upward movement to the unsaturated zone), if present, has not been quantified. However, consistent with the above discussion of net infiltration, DOE believes that there is a net downward movement of water in the unsaturated zone in the vicinity of Yucca Mountain.

Use. Two wells, J-12 and J-13 (shown in Figure 3-20), are part of the water system for site characterization activities at Yucca Mountain. These are the nearest production wells to Yucca Mountain and they support water needs for Area 25 of the Nevada Test Site and for Exploratory Studies Facility activities. Both of these wells withdraw groundwater from the Jackass Flats hydrographic area, as listed in Table 3-11. Groundwater has also been pumped from the Jackass Flats area from various boreholes for hydraulic testing, and most recently from the C-well complex, which consists of three separate wells grouped in an area just east of the South Portal Development Area (DIRS 100465-Luckey et al. 1996, Figure 17). In addition, water has been pumped occasionally from borehole USW VH-1 (also designated CF-2) in support of Yucca Mountain characterization activities. But the volume pumped from this well, which is in the Crater Flat hydrographic area, is small (DIRS 100465-Luckey et al. 1996, p. 70).

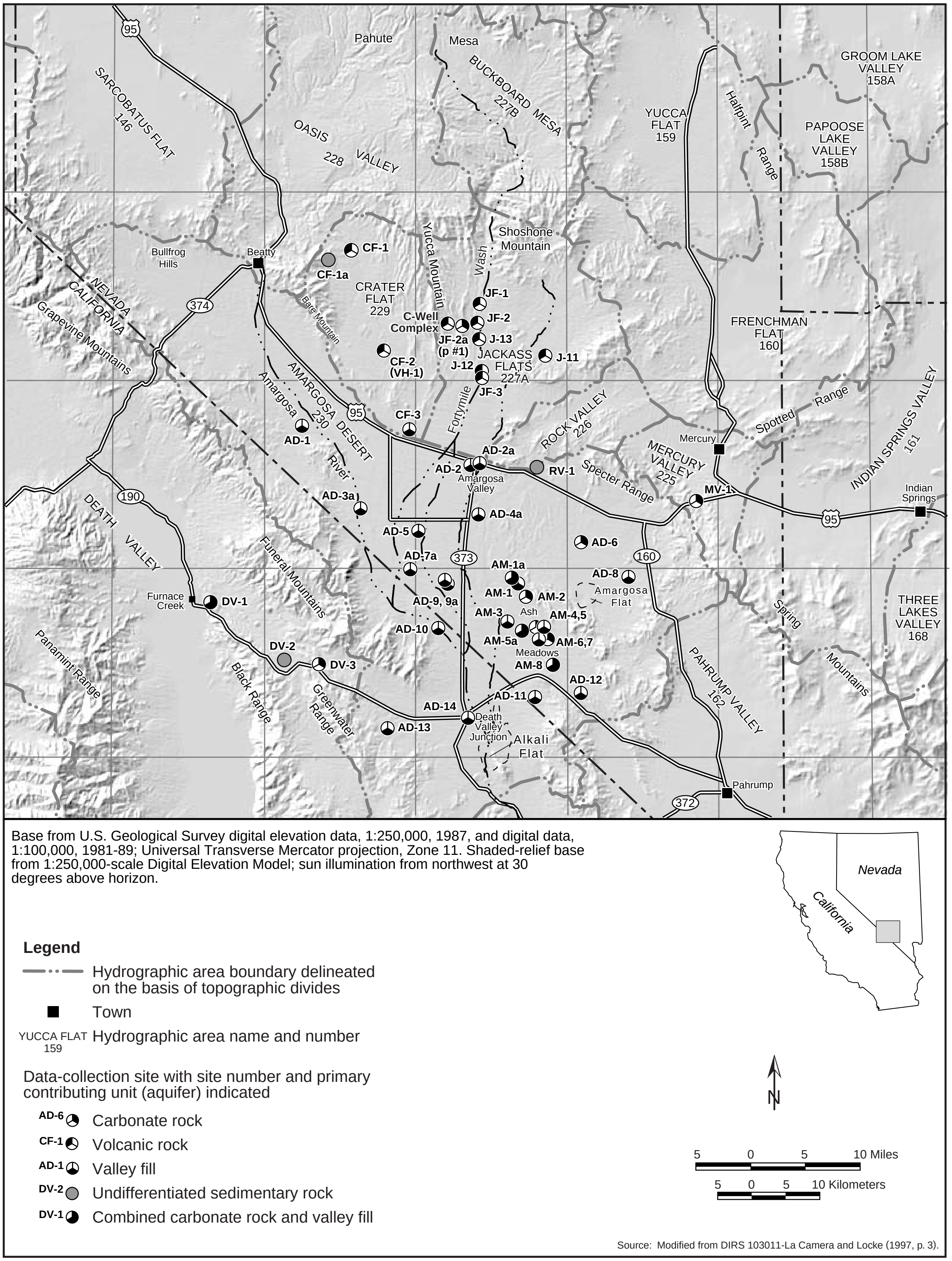


Figure 3-20. Selected groundwater data-collection sites in the Yucca Mountain region.

The Yucca Mountain Site Characterization Project has received water appropriation permits (Numbers 57373, 57374, 57375, and 57376) from the State of Nevada for wells J-12, J-13, VH-1 (also known as CF-2), and the C-Well complex (Numbers 58827, 58828, and 58829), and a Potable Water Supply permit (NY-0867-12NCNT) for the distribution system. The permits allow a maximum pumping rate of about 0.028 cubic meter (1 cubic foot) a second, with a maximum yearly withdrawal of about 530,000 cubic meters (430 acre-feet) (DIRS 151945-CRWMS M&O 2000, p. 9.5-3 and 9.5-4, and Table 9.5-3, p. T9.5-3). The permit limits apply to site characterization water use. Table 3-16 lists historic and projected water use from wells J-12 and J-13 from 1992 to 2005 for the Exploratory Studies Facility and Concrete Batch Plant, and from the C-Wells, which is pumped and then reinjected as part of aquifer testing. It also lists the total amount of water pumped from wells J-12 and J-13 for both Yucca Mountain and the Nevada Test Site. The difference between the quantities pumped from wells J-12 and J-13 for Yucca Mountain activities and the total withdrawals from these wells represents the quantities used for Nevada Test Site activities in the area. The water-use projections in Table 3-16 are through the end of site characterization activities; Section 4.1.3 discusses water demand projections for the proposed repository.

Table 3-16. Water withdrawals (acre-feet)[a] from wells in the Yucca Mountain vicinity.

Year	J-12 and J-13 Yucca Mountain characterization[b]	J-12 and J-13 total withdrawals[c]	C-wells[b]
1992	18	120	0
1993	80	210	0
1994	75	280	0
1995	94	260	19
1996	66	220	180
1997	63	150	190
1998	63[d]	N/A[e]	190[f]
1999	63	N/A	N/A
2005	63	N/A	N/A

a. To convert acre-feet to cubic meters, multiply by 1233.49.
b. Source: DIRS 104988-CRWMS M&O (1999, p. 4).
c. Source: DIRS 103171-Clary et al. (1995, p. 660); DIRS 101486-Bauer et al. (1996, p. 702); DIRS 103090-Bostic et al. (1997, p. 592); DIRS 103082-Bonner et al. (1998, p. 606); DIRS 103283-La Camera, Locke, and Munson (1999, all); withdrawals for 1992 and 1993 were estimated from figures in DIRS 103011-La Camera and Locke (1997, p. 51).
d. Assumed to remain constant from 1997 through 2005.
e. N/A = not available.
f. Assumed to remain constant from 1997 to 1998.

The U.S. Geological Survey, in support of Yucca Mountain characterization efforts and in compliance with the State permits, has kept records of the amount of water pumped from the J-12 and J-13 wells and of measured water elevation levels in those and other wells in their immediate area since 1992 (DIRS 103011-La Camera and Locke 1997, pp. 1 and 2). One of the objectives of keeping these records is to detect and document changes in groundwater resources during the Yucca Mountain investigations. Therefore, the Survey effort included the collection of historic water elevation data to establish a baseline. Results from these efforts have been documented in annual reports. The report for 1997 (DIRS 103283-La Camera, Locke, and Munson 1999, all) includes a summary of 1996 results and detailed results for 1997. Table 3-17 summarizes the changes observed in median groundwater elevations in seven wells in Jackass Flats. The second column of the table identifies the historic or baseline elevation for each well against which the annual median values are being compared. In addition, the table lists the average deviation of measured water levels during the period from which the baseline was generated.

Table 3-17. Differences between annual median elevations and baseline median elevations.[a]

Well	Baseline elevations: Median (meters[c] above sea level)	Baseline elevations: Average deviation about the median (centimeters)	Difference (in centimeters[b]) baseline: 1992	1993	1994	1995	1996	1997
JF-1	729.23	± 6	–3	0	–6	0	–6	–3
JF-2	729.11	± 9	+3	0	+3	+9	0	–3
JF-2a[d]	752.43	± 12	0	+6	+12	+15	+21	+27
J-13	728.47	± 6	–3	–3	–9	–6	–12	–12
J-11	732.19	± 3	0	0	+3	+6	+6	+12
J-12	727.95	± 3	0	0	–3	–3	–9	–9
JF-3	727.95	± 3	N/A[e]	N/A	–6	–6	–9	–9

a. Source: DIRS 103283-La Camera, Locke, and Munson (1999, Table 10).
b. To convert centimeters to inches, multiply by 0.3937.
c. To convert meters to feet, multiply by 3.2808.
d. Well JF-2a is also known as UE-25 p#1, or P-1.
e. N/A = not available.

The elevation changes listed in Table 3-17 are different from the short-term fluctuations described above that are a response to changes in barometric pressure and Earth tides. The differences in comparison of annual median values should indicate water level trends, if there are any. The data show that a decline in groundwater elevation has been seen in some, but not all, of the local wells. Specifically, the data show the following:

- Two wells, JF-1 and JF-2, stayed within the band of elevations characteristic of the baseline data.
- Two wells, JF-2a (also known as UE-25 p#1, or P-1) and J-11, indicated elevation increases of 15 and 9 centimeters (about 5.9 and 3.5 inches), respectively, above the band of elevations characteristic of the baseline data (and even higher above the median of the baseline data as listed in the table).
- Three wells, J-13, J-12, and JF-3, each indicated an elevation decrease of 6 centimeters (about 2.4 inches) below the band of elevations characteristic of the baseline data (and even further below the median of the baseline data as listed in the table).

In its discussion of groundwater levels, the U.S. Geological Survey (DIRS 103011-La Camera and Locke 1997, p. 22) indicated that monitoring of water levels in the seven wells should continue to see if additional decreases occur and if they can be correlated to periods of withdrawal. In regard to overall groundwater levels in the Jackass Flats area, the data do not appear to show any definitive trend in elevation change, either up or down. However, the three wells showing a water decline are either being pumped (J-12 and J-13) or, in the case of JF-3, are close to a production well. Of the two wells (JF-2a and J-11) showing water-level increases, one (JF-2a) penetrates the lower carbonate aquifer and the other, though penetrating a volcanic aquifer, is farthest from the production wells of any shown on the table. Pumping from the volcanic aquifer production wells would be unlikely to affect either of these wells. There is some speculation that the consistent water-level increase over time in well JF-2a might indicate that it has not yet reached an *equilibrium* elevation.

Saturated Zone Groundwater Quality. Groundwater quality for the aquifers beneath Yucca Mountain was addressed by the Geological Survey sampling and analysis effort described above for regional groundwater quality. This effort included the collection and analysis of samples from three wells in the Jackass Flats area (including J-12 and J-13); the results indicated that the concentrations of dissolved substances in local groundwater were below the numerical criteria of the primary drinking water standards set by the Environmental Protection Agency for public drinking water systems (DIRS 104828-Covay 1997, all). However, samples from each of the wells exceeded the secondary standard for fluoride, as they did for a proposed standard for radon. Both of these constituents occur naturally in the rock through which the groundwater flows. Overall, local groundwater quality is generally good.

Investigations of the chemical and mineral composition of groundwater at Yucca Mountain have provided an indication of the differences between the aquifers beneath the site. The chemical composition of groundwater depends on the chemistry of the recharge water and the chemistry of the rocks through which the water travels. Water in the volcanic aquifers and confining units at Yucca Mountain has a relatively dilute sodium-potassium-bicarbonate composition that probably results from the *dissolution* of volcanic tuff (Table 3-18). The chemistry of water from the lower carbonate aquifer is very different (a generally more concentrated calcium-magnesium-bicarbonate composition), which would be expected from water traveling through and dissolving carbonate rock (Table 3-18).

Table 3-18. Water chemistry of volcanic and carbonate aquifers at Yucca Mountain (milligrams per liter).[a]

Chemical constituent	Chemical composition: Volcanic aquifers[b]	Chemical composition: Lower carbonate aquifer[c]
Calcium	1.4 - 37	100
Magnesium	< 0.01 - 10	39
Potassium	1.1 - 5.6	12
Sodium	38 - 120	150
Bicarbonate	110 - 282	569
Chloride	5.5 - 13	28
Sulfate	16 - 45	160
Silica	40 - 57	41

a. Source: DIRS 101036-Benson and McKinley (1985, Table 1, p. 5).
b. Based on samples from 14 wells.
c. Based on samples from one well.

As part of the Yucca Mountain project, well and spring monitoring activities performed during 1997 aided the establishment of a baseline for radioactivity in groundwater near the site of the proposed repository (DIRS 104963-CRWMS M&O 1998, all). The quarterly sampling included six wells and two springs that were selected to ensure that at least two were representative of each of the three general aquifers (carbonate, volcanic, and alluvial) in the region. Samples were analyzed for gross alpha, gross beta, total uranium, and concentrations of selected beta and gamma-emitting radionuclides. Table 3-19 lists the results from this monitoring as average values from the quarterly sampling events for each well or spring. The table lists the location of each well or spring, including the data collection site designations shown on Figure 3-20, the contributing aquifer, and a comparison, if applicable, to *Maximum Contaminant Levels* established by the Environmental Protection Agency for water supplied by public drinking water systems. As indicated in the table, the sites sampled include locations outside the Alkali Flat-Furnace Creek groundwater basin in which Yucca Mountain is located. The Cherry Patch location is in the Ash Meadows groundwater basin and Crystal Pool and Fairbanks Spring are on the border between the two basins, but are fed by flow through Ash Meadows. The location variety supports area comparisons as well as comparisons between the different contributing aquifers.

Table 3-19 indicates that Maximum Contaminant Levels for combined radium-226 and radium-228 and for gross alpha were not exceeded by the average values from any of the sampling sites or by the maximum values reported for those parameters (DIRS 104963-CRWMS M&O 1998, pp. 12 to 21). The samples were analyzed for other beta- or gamma-emitting radionuclides, specifically tritium, carbon-14, chlorine-36, nickel-59, strontium-89, strontium-90, technetium-99, iodine-129, and cesium-137. The table does not list the results for these parameters because they are below minimum detectable activity (DIRS 104963-CRWMS M&O 1998, p. 13). As a conservative measure, however, DOE used the values reported by the laboratory to calculate dose contributions (DIRS 104963-CRWMS M&O 1998, Appendix F). Water from each sampling location was shown to have exposure values well below the 4-millirem-per-year total body (or any internal organ) dose limit set as the Maximum Contaminant Level for beta- or gamma-emitting radionuclides.

Table 3-19. Results of 1997 groundwater sampling and analysis for radioactivity.[a]

Site name and location description[b]	Contributing aquifer	Average combined radium-226 and -228 (picocuries per liter)	Average gross alpha (picocuries per liter)	Average total uranium[c] (micrograms per liter)	Average gross beta (picocuries per liter)	Average radon-222 (picocuries per liter)
J-12 and J-13[d] Fortymile Wash, SE of Yucca Mtn.	Volcanic	0.32±0.24	BDL[e]	0.52±0.03	6.04±0.60	384
C-3 (C-well complex) By South Portal, SE of Yucca Mtn.	Volcanic	0.58±0.36	1.34±1.05	1.04±0.09	3.59±0.76	763
Crystal Pool (Spring) (AM-5a) Ash Meadows	Carbonate/ alluvial[f]	0.93±0.20	BDL	2.64±0.23	14.0±1.28	447
Fairbanks Spring (AM-1a) Ash Meadows	Carbonate/ alluvial	0.80±0.36	BDL	2.23±0.19	11.1±1.17	279
Nevada Department of Transportation Well (AD-2a) Amargosa Valley	Alluvial	0.32±0.33	BDL	2.55±0.22	5.95±0.93	612
Gilgans South Well (AD-9a) Amargosa Desert	Alluvial	0.19±0.31	BDL	0.63 ± 0.05	9.14±0.97	600
Cherry Patch Well (AD-8) NE of Ash Meadows	Alluvial	0.22±0.33	9.19±4.35	13.1 ± 1.16	18.7±1.65	504
Drinking water Maximum Contaminant Levels[g]		5	15	NA[h]	NA	300 (proposed)

a. Source: DIRS 104963-CRWMS M&O 1998, pp. 12 to 21) for all but radon-222 data; DIRS 104828-Covay (1997, Table 4) for radon data.
b. Figure 3-20 shows the locations of the wells.
c. To convert total uranium concentrations in micrograms per liter to picocuries per liter, multiply by 0.68 (DIRS 104963-CRWMS M&O 1998, p. 15).
d. Average of data presented for Well J-12 and Well J-13.
e. BDL = below detection limit.
f. Alluvium is also identified as valley fill in DIRS 151945-CRWMS M&O (2000, p. 9.2-23).
g. Drinking water Maximum Contaminant Levels are set by the Environmental Protection Agency in 40 CFR Part 141.
h. NA = not applicable.

There is no indication that DOE activities at the Nevada Test Site have contaminated the groundwater beneath Yucca Mountain. This is consistent with studies performed on the Nevada Test Site. DIRS 103411-Nimz and Thompson (1992, all) documented about a dozen instances in which radionuclides have migrated into the groundwater from areas of nuclear weapons testing at the Nevada Test Site in 40 years. The maximum distance of tritium migration is believed to be several kilometers; less mobile radioactive constituents, which include a wide variety of isotopes (DIRS 101811-DOE 1996, pp. 4-126 to 4-129), have migrated no more than about 500 meters (1,600 feet). There has, however, been recent evidence of plutonium migration from one below-groundwater test at Pahute Mesa.

Groundwater monitoring results indicate plutonium has migrated at least 1.3 kilometers (0.8 mile) from this site in 28 years and is apparently associated with the movement of very small particles called colloids (DIRS 103282-Kersting et al. 1999, p. 56). None of the nuclear testing occurred in Area 25 where the Yucca Mountain Repository facilities would be. However, the flow of groundwater from areas on Pahute and Buckboard Mesas where DOE conducted 81 and 2 nuclear tests, respectively, could be to the south toward Yucca Mountain. The distance is about 40 kilometers (25 miles) to Pahute Mesa and about 30 kilometers (19 miles) to Buckboard Mesa (Figure 3-20). Because of these distances, there is no reason to believe that radionuclides from nuclear tests could migrate as far as Yucca Mountain during the active life (construction, operation and monitoring, and closure phases) of the repository, with the possible exception of tritium. Conservative modeling performed by DOE at the Nevada Test Site (DIRS 103021-DOE 1997, pp. ES-27 to ES-29, and ES-36) shows that tritium, moving with little or no attenuation in groundwater other than decay, could move to locations at or near Nevada Test Site boundaries in tens of years. However, the same study reports that monitoring has not shown tritium to be moving as rapidly as predicted when using the conservative assumptions of the model. In addition, the flow paths from the underground nuclear testing areas, as predicted in this study, do not intersect groundwater beneath Yucca Mountain. Chapter 8 discusses the potential for long-term migrations of radionuclides to result in cumulative radiation from nuclear testing contamination eventually migrating through the groundwater system and joining groundwater beneath the repository.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

The region of influence for biological resources and soils is the area that contains all potential surface disturbances that would result from the Proposed Action plus some additional area to evaluate local animal populations. This region is roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (230 square miles). DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

DOE has surveyed the region for naturally occurring wetlands and has studied soil characteristics (thicknesses, water-holding capacity, texture, and erosion hazard) in the region. This section summarizes this information and describes existing soil conditions in relation to potential contaminants. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all) or the *Environmental Baseline File for Soils* (DIRS 104592-CRWMS M&O 1999, all).

The State of Nevada (DIRS 148188-Loux 1997, all) expressed the view that there was no systematic integrated environmental program to characterize the unique and fragile desert environment at Yucca Mountain before 1982, when DOE began site investigation that may have caused irreversible alterations (DIRS 103298-Lemons and Malone 1989, pp. 435 to 441). However, the State acknowledged that after site investigations started and impacts might have occurred, DOE began studies of sensitive species, archaeology, airborne particulates, and groundwater (DIRS 103298-Lemons and Malone 1989, pp. 435 to 441), and established an environmental baseline from these data (DIRS 103396-Malone 1989, pp. 77 to 95). DIRS 103398-Malone (1995, pp. 271 to 284) contended that many of the studies conducted to establish the baseline and evaluate impacts, particularly those on plants and animals, were not adequately designed and did not use an integrated ecosystem approach and, therefore, were of little value for evaluating impacts of the repository.

DOE contends that studies initiated after the start of site investigations are suitable for establishing the baseline needed for this EIS. The purpose of studies of the impacts of site characterization activities on plants and animals was not to evaluate potential impacts from a repository, but rather to focus on the appropriate level of ecological organization for the types of impacts that occurred during characterization activities. DOE used the results of those studies in the EIS analysis to understand and predict possible impacts from similar activities that would occur during repository construction and operation (for example, habitat destruction).

3.1.5.1 Biological Resources

3.1.5.1.1 *Vegetation*

DOE adapted broad categories of land cover types for the analyzed land withdrawal area (based primarily on predominant vegetation; see Figure 3-21) from two sources: a statewide classification and a detailed, field-validated classification of the area surrounding the location of the proposed repository. Land cover types typical of the Mojave and Great Basin Deserts occur in the analyzed land withdrawal area; they include creosote-bursage (56 percent), blackbrush (14 percent), hopsage (13 percent), Mojave mixed scrub (10 percent), salt desert scrub (4 percent), sagebrush (3 percent), and pinyon-juniper (much less than 1 percent). None of the more than 210 plant species known to occur in the analyzed land withdrawal area is endemic to the area; that is, they all occur in other places.

3.1.5 BIOLOGICAL RESOURCES AND SOILS

The region of influence for biological resources and soils is the area that contains all potential surface disturbances that would result from the Proposed Action plus some additional area to evaluate local animal populations. This region is roughly equivalent to the analyzed land withdrawal area of about 600 square kilometers (230 square miles). DOE used available information and studies on plants and animals at the site of the proposed repository and the surrounding region to identify baseline conditions for biological resources. This information included land cover types, vegetation associations, and the distribution and abundance of plant and animal species in the region of influence (the analyzed land withdrawal area) and in the broader region. The plants and animals in the Yucca Mountain region are typical of species in the Mojave and Great Basin Deserts.

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Plant species typical of the Mojave Desert dominate the vegetation at low elevations in the analyzed land withdrawal area. Low-elevation valleys, alluvial fans, and large washes are dominated by white bursage (*Ambrosia dumosa*), creosotebush (*Larrea tridentata*), Nevada jointfir (*Ephedra nevadensis*), littleleaf ratany (*Krameria erecta*), and pale wolfberry (*Lycium pallidum*). Low-elevation hillsides are dominated by similar species, with the addition of shadscale (*Atriplex confertifolia*), California buckwheat (*Eriogonum fasciculatum*), and spiny hopsage (*Grayia spinosa*).

At higher elevations, generally at the northern end of the analyzed land withdrawal area, species typical of the Great Basin Desert are dominant. Ridge tops and slopes are dominated by blackbrush (*Coleogyne ramosissima*), heathgoldenrod (*Ericameria teretifolius*), Nevada jointfir, broom snakeweed (*Gutierrezia sarothrae*), green ephedra (*Ephedra viridis*), and California buckwheat. On some steep north-facing slopes, big sagebrush (*Artemisia tridentata*) is predominant.

There are approximately 30 exotic plant species present in the Yucca Mountain area. The most common species include red brome (*Bromus rubens*), Russian thistle (*Salsola* spp.), tumble mustard (*Sisymbrium altissimum*), halogeton (*Halogeton glomeratus*), and Arabian schismus (*Schismis arabicus*). Red brome is the most abundant exotic species in the area. None of these exotic species is on the State of Nevada's Noxious Weed List (DIRS 155925-NWAC 2000, Appendix A).

3.1.5.1.2 *Wildlife*

Wildlife at Yucca Mountain is dominated by species associated with the Mojave Desert, with some species from the Great Basin Desert at higher elevations.

The 36 species of mammals that have been observed in the analyzed Yucca Mountain land withdrawal area include 17 species of rodents, seven species of bats, three species of rabbits and hares, and nine species of large mammals such as coyote *(Canis latrans)*, mule deer *(Odocoileus hemionus)*, and burros (*Equus asinus*). The most abundant species are long-tailed pocket mice *(Chaetodipus formosus*) and Merriam's kangaroo rats (*Dipodomys merriami*).

The 27 species of reptiles include 12 species of lizards, 14 species of snakes, and the desert tortoise (*Gopherus agassizii*). The most abundant lizard is the side-blotched lizard (*Uta stansburiana*), while the western whiptail (*Cnemidophorus tigris*) is common. The most abundant snakes are the coachwhip (*Masticophis flagellum*) and the long-nosed snake (*Rhinocheilus lecontei*). No amphibians have been found at Yucca Mountain.

There have been no formal attempts to quantify the birds present at Yucca Mountain, but at least 120 species have been sighted in or near the analyzed land withdrawal area, including 14 species that nest there. Transient and resident species have been recorded including species typical of the desert, migrating water birds and warblers, and raptors. Black-throated sparrows (*Amphispiza bilineata*) are the most common resident birds and mourning doves (*Zenaida macroura*) are seasonally common.

Researchers have collected invertebrates from 18 orders and 53 families at Yucca Mountain. Members of the insect orders Lepidoptera (butterflies and moths), Hymenoptera (bees, wasps, and ants), and Coleoptera (beetles) were the most numerous of those collected.

Several game species and furbearers (see Nevada Administrative Code 503.125) have been observed in the analyzed land withdrawal area, including (1) three species of game birds—Gambel's quail (*Callipepla gambelii*), chukar (*Alectoris chukar*), and mourning doves, (2) mule deer (*Odocoileus hemionus*), and (3) three species of furbearers—kit foxes (*Vulpes velox*), mountain lions (*Puma concolor*), and bobcats (*Lynx rufus*).

3.1.5.1.3 *Special Status Species*

No plant species listed as threatened or endangered or that are proposed or candidates for listing under the Endangered Species Act occur in the analyzed land withdrawal area. No plant species classified as sensitive by the Bureau of Land Management are known to occur in the analyzed land withdrawal area. Several species of cacti and yucca, all of which are protected by the State of Nevada from commercial collection, are scattered throughout the region, including the analyzed land withdrawal area.

SPECIAL STATUS SPECIES

An **endangered species** is classified under the Endangered Species Act as being in danger of extinction throughout all or a significant part of its range.

A **threatened species** is classified under the Endangered Species Act as likely to become an endangered species in the foreseeable future.

Candidate species are species for which the Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

The State of Nevada has also designated special status species as endangered, threatened, protected, and sensitive. Species with these classifications are protected under Nevada Administrative Code Chapter 503.

Bureau of Land Management **sensitive species** include species designated by the Bureau's State Director in addition to those listed, proposed, or candidates under the Endangered Species Act or listed by the State of Nevada as endangered or otherwise protected.

One animal species that occurs at Yucca Mountain, the desert tortoise, is listed as threatened under the Endangered Species Act. Yucca Mountain is at the northern edge of the range of the desert tortoise (DIRS 101915-Rautenstrauch, Brown, and Goodwin 1994, p. 11), and the abundance of tortoises at Yucca Mountain is low or very low in comparison to other portions of its range. Aspects of the ecology of the desert tortoise population at Yucca Mountain have been studied extensively (DIRS 104593-CRWMS M&O 1999, all).

Individual bald eagles (*Haliaeetus leucocephalus)* and peregrine falcons (*Falco peregrinus)* occasionally migrate through the region; these species have been seen once each at the Nevada Test Site. Both species are rare in the region and have not been seen at Yucca Mountain. Bald eagles are classified as threatened under the Endangered Species Act, and the State of Nevada classifies both birds as endangered.

No other Federally listed threatened or *endangered species* or candidates for listing under the Endangered Species Act occur at Yucca Mountain.

Five species classified as sensitive by the Bureau of Land Management occur at Yucca Mountain. Two species of bats—the long-legged myotis (*Myotis volans*) and the fringed myotis (*M. thysanodes*)—have been observed near the site. Three other species, the western chuckwalla (*Sauromalus obesus*), burrowing owl (*Speotyto cunicularia*), and Giuliani's dune scarab beetle (*Pseudocotalpa giulianii*), occur in the analyzed land withdrawal area. The chuckwalla, one of the largest lizards in Nevada, is locally common and widely distributed in rocky habitats throughout the analyzed land withdrawal area and the surrounding region. The seldom-seen burrowing owl generally occurs in valley bottoms and is known to be a year-round resident at the Nevada Test Site. Giuliani's dune scarab beetle has been found near the cinder cones north of U.S. Highway 95 at the south end of Crater Flat.

Ash Meadows National Wildlife Refuge and Devils Hole (which is administered as part of Death Valley National Park) are about 39 kilometers (24 miles) south of Yucca Mountain. Although Ash Meadows and Devils Hole are outside the region of influence for biological resources, they contain a number of special status species that an evaluation of regional biological resources should consider. Of the eight endemic plant species at Ash Meadows, one is listed as endangered (Amargosa alkali plant, *Nitrophila mohavensis*) and six are listed as threatened (Spring-loving centaury, *Centaurium namophilum*; Ash Meadows milkvetch, *Astragalus phoenix*; Ash Meadows naked stem sunray, *Enceliopsis nudicaulis* var. *corrugata*; Kings Mousetail, *Ivesia kingii* var. *eremica*; Ash Meadows gumweed, *Grindelia fraximopratensis*; and Ash Meadows blazing star, *Mentzelia leucophylla*) (50 *FR* 20777, May 20, 1985). Four endemic fish species occur in the springs and pools. The Fish and Wildlife Service and the State of Nevada list these species—the Ash Meadows Amargosa speckled dace (*Rhinichthys osculus nevadensis*), Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*), Devils Hole pupfish (*C. diabolis*), and Warm Springs Amargosa pupfish (*C. nevadensis pectoralis*)—as endangered. The springs also provide habitat for a number of endemic riffle beetles, springsnails, and other invertebrates, including the threatened Ash Meadows naucorid bug (*Ambrysus amargosus*).

3.1.5.1.4 *Wetlands*

There are no naturally occurring jurisdictional wetlands (wetlands that are regulated under Section 404 of the Clean Water Act) at Yucca Mountain. Four manmade ponds in the Yucca Mountain region have *riparian* vegetation. Fortymile Wash and some of its tributaries might be classified as waters of the United States as defined by the Clean Water Act. Jurisdictional wetlands associated with Ash Meadows are outside the region of influence for the Proposed Action.

3.1.5.2 Soils

Researchers have conducted a soil survey centered on Midway Valley (the location of the proposed North Portal facilities) and the ridges to the west (DIRS 103450-Resource Concepts 1989, all), and a more general soil survey of the entire Yucca Mountain region (DIRS 104851-YMP 1997, all). The survey that centered on Midway Valley identified 17 soil series and seven map units (Table 3-20) at Yucca Mountain (DIRS 103450-Resource Concepts 1989, all); none of these series is classified as *prime farmland*. Based on a wetlands assessment at the Nevada Test Site (DIRS 101833-Hansen et al. 1997, all), there are no hydric soils at Yucca Mountain. Yucca Mountain soils are derived from underlying volcanic rocks and mixed alluvium dominated by volcanic material, and in general have low water-holding capacities.

SOIL TERMS

Prime farmland: Land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is available for these uses (urban areas are not included). It has the soil quality, growing season, and moisture supply needed for the economic production of sustained high yields of crops when treated and managed (including water management) according to acceptable farming methods (Farmland Protection Policy Act of 1981, 7 CFR 7.658).

Piedmont: Land lying along or near the foot of a mountain. For example, a fan piedmont is a fan-shaped landform between the mountain and the basin floor.

The shallow soils on ridge tops at Yucca Mountain often consist of a thin *hardpan* (hardened or cemented soil layer) on top of bedrock and range from *well drained* to

Table 3-20. Soil mapping units at Yucca Mountain.[a]

Map unit	Percent	Geographic setting	Soil characteristics
Upspring-Zalda	11	Mountain tops and ridges. Soils occur on smooth, gently sloping ridge tops and shoulders and on nearly flat mesa tops. Rhyolite and tuffs are parent materials for both soil types.	Typically shallow (10 - 51 cm[b]) to bedrock, or to thin duripan[c] over bedrock. They are well to excessively drained, have low available water-holding capacity, medium to rapid runoff potential, and slight erosion hazard.
Gabbvally-Downeyville-Talus	8	North-facing mountain sideslopes. Talus is stone-sized rock occurring randomly throughout unit in long, narrow, vertically oriented accumulations.	Shallow (10 - 36 cm) to bedrock. Permeability is moderate to moderately rapid. They have moderate to rapid runoff potential, are well drained, and have low available water-holding capacity and moderate erosion hazard.
Upspring-Zalda-Longjim	27	Mountain sideslopes. Soils occur on south-, east-, and west-facing slopes, and on moderately sloping alluvial deposits below sideslopes.	Shallow (10 - 51 cm) to bedrock or to thin duripan over bedrock. They are well to excessively drained and have moderately rapid to rapid permeability and runoff potential, very low available water-holding capacity, and slight erosion hazard.
Skelon-Aymate	22	Alluvial fan remnants. Soils occur on gently to strongly sloping summits and upper sideslopes.	Moderately deep (51 - 102 cm) to indurated[d] duripan or petrocalcic[e] layer with low to very low available water-holding capacity, moderately rapid permeability, slow runoff potential, and slight erosion hazard.
Strozi variant-Yermo-Bullfor	7	Alluvial fan remnants. Soils occur on gently to moderately sloping alluvial fan remnants and stream terraces adjacent to large drainages.	Moderately deep (51 - 102 cm) to deep (102 cm). They are well drained and have rapid permeability, very low available water-holding capacity, slow runoff potential, and slight erosion hazard.
Jonnic variant-Strozi-Arizo	12	Dissected alluvial fan remnants. Soils occur on fan summits, moderately sloping fan sideslopes, and inset fans. They are formed in alluvium from mixed volcanic sources.	Moderately deep (36 - 43 cm) to deep (more than 102 cm), sometimes over strongly cemented duripan. They have slow or rapid permeability, slow or moderate runoff potential, very low available water-holding capacity, and slight erosion hazard.
Yermo-Arizo-Pinez	13	Inset fans and low alluvial sideslopes in mountain canyons; and drainages between fan remnants. Soils occur on moderately to strongly sloping inset fans near drainages, adjacent to lower fan remnants, and below foothills.	Deep (more than 102 cm), sometimes over indurated duripan. They are well drained and have very low available water holding-capacity, moderately slow to rapid permeability, slow to medium runoff potential, and slight erosion hazard.

a. Source: DIRS 104592-CRWMS M&O (1999, pp. 3 and 4).
b. To convert centimeters (cm) to inches, multiply by 0.3937.
c. Duripan: A subsurface layer cemented by silica, usually containing other accessory cements.
d. Indurated: Hardened, as in a subsurface layer that has become hardened.
e. Petrocalcic: A subsurface layer in which calcium carbonate or other carbonates have accumulated to the extent that the layer is cemented or indurated.

excessively drained, which means that water drains readily to very rapidly. The soil has a topsoil layer typically less than 15 centimeters (6 inches) thick and, in some instances, a subsoil layer 5 to 30 centimeters (2 to 12 inches) thick. Soil textures range from gravelly to cobbly, loamy sands to sandy loams. Soils are calcareous (high in calcium carbonate), with lime coatings on the undersides of rocks in the subsoil layer. The soils are moderately to strongly alkaline, with a *pH* ranging from 8.0 to 8.6. Rock fragments ranging in size from gravel to cobbles dominate 45 to 65 percent of the ground surface.

Soils on fan piedmonts and in steep, narrow canyons are relatively deep and are *well drained* (water is drained readily, but not rapidly). These soils developed from residues of volcanic parent material, with a component of calcareous eolian sand. Soils formed from the volcanic parent material generally range from *moderately shallow* [50 to 75 centimeters (20 to 30 inches)] to *moderately deep* [75 to 100 centimeters (30 to 40 inches)] over a thin hardpan on top of bedrock. The topsoil layers are generally less than 25 centimeters (10 inches) thick, with a subsoil layer thickness of 25 to 50 centimeters (10 to 20 inches). The mixed soils, containing residues from volcanic parent material and calcareous eolian sand, are often *deep* [100 to 150 centimeters (40 to 60 inches)] or moderately deep, having a well-cemented hardpan. The topsoil layers are less than 15 centimeters (6 inches) thick, with the layer of soil parent material as deep as 150 centimeters (60 inches). Soil textures are gravelly, sandy loams with 35 to 70 percent rock fragments. Soils are generally calcareous and moderately to strongly alkaline.

Soils on alluvial fans and in stream channels are *very deep* [greater than 150 centimeters (60 inches)] and range from well drained to excessively drained. The topsoil layers are generally less than 20 centimeters (8 inches) thick, with the layer of soil parent material as deep as 150 centimeters. Soil textures are very gravelly, with fine sands to sandy loams and abundant rock fragments. The soils are calcareous and moderately alkaline.

The Yucca Mountain site characterization project has sampled and analyzed surface soils for radiological constituents. In addition, records of spills or releases of nonradioactive materials have been maintained to meet regulatory requirements and to provide a baseline for the Proposed Action. A recent summary of existing radiological conditions in soils is based on 98 surface samples collected within 16 kilometers (10 miles) of the Exploratory Studies Facility. The results of that analysis, when compared to other parts of the world, indicate average levels of the naturally occurring radionuclide uranium-238 series decay products and above-average levels of the naturally occurring radionuclides potassium-40 and thorium-232 series decay products. The higher-than-average radionuclide values might be due to the origin of the soil at the site from tuffaceous igneous rocks. The studies also detected concentrations of the manmade radionuclides strontium-90, cesium-137, and plutonium-239 from worldwide nuclear weapons testing.

3.1.6 CULTURAL RESOURCES

Cultural resources include any prehistoric or historic district, site, building, structure, or object resulting from or modified by human activity. Cultural resources could also include potential *traditional cultural properties*. Under Federal regulation, cultural resources designated as historic properties warrant consideration with regard to potential adverse impacts resulting from proposed Federal actions. A cultural resource is an historic property if its attributes make it eligible for listing or it is formally listed on the *National Register of Historic Places*. For this analysis, DOE has

CULTURAL RESOURCES

Archaeological site: The location of a past event, a prehistoric or historic occupation or activity, or a building or structure, whether standing, ruined, or vanished, where the location itself maintains archaeological value.

Traditional cultural property: A property associated with the cultural practices or beliefs of a living community that are (1) rooted in that community's history, and (2) important in maintaining the cultural identity of the community.

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evaluated the importance of historic and archaeological resources according to National Register eligibility criteria.

Cultural resources at Yucca Mountain include archaeological resources that are prehistoric or historic, and other resources important to Native American tribes and organizations, such as potential traditional cultural properties. The region of influence for cultural resources includes the land areas that would be disturbed by the proposed repository activities (as described in Chapter 2) and areas in the analyzed land withdrawal area where impacts could occur. DOE has collected information on the various types of archaeological sites, detailing their purposes and the kinds of artifacts typically present. DOE also has focused on Native American interests in the region's cultural resources. Section 3.1.6.2 summarizes these issues in discussions of Native American views of the affected environment.

Unless otherwise indicated, the information in this section is derived from either the summary of past archaeological projects at Yucca Mountain (DIRS 104997-CRWMS M&O 1999, all) or from *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all).

3.1.6.1 Archaeological and Historic Resources

Site characterization efforts have led to a number of archaeological investigations at Yucca Mountain over the past two decades, including, as an early action, an archaeological field survey of a 44-square-kilometer (about 11,000-acre) parcel that proposed repository activities probably would affect. The field survey was followed by limited test excavations at 29 sites to determine their scientific importance and to develop management strategies for the protection of archaeological resources. Additional archaeological surveys have been conducted along nearby Midway Valley and Yucca Wash, in lower Fortymile Canyon just east of the Yucca Mountain site, and around Dune Wash east of southern Yucca Mountain.

Concurrent with these investigations, DOE directed archaeological surveys and data-recovery projects before beginning planned ground-disturbing activities specific to the Yucca Mountain Project. Limited data-recovery efforts at 18 archaeological sites support a model for a local cultural sequence that includes a pattern of linear-shaped sites along major drainages dating as far back as 7,000 years, and a shift to a more dispersed pattern of sites about 1,500 years ago. A site monitoring program designed to examine human and natural impacts to cultural resources through time began in 1991 and is continuing at Yucca Mountain.

Decades of cultural resource investigations at Yucca Mountain and at the Nevada Test Site have revealed archaeological features and artifacts. Based on archaeological site file searches at the Desert Research Institute in Las Vegas and Reno and at the Harry Reid Center at the University of Nevada, Las Vegas, approximately 830 archaeological sites have been discovered in the analyzed land withdrawal area. Most of the known archaeological sites are small scatters of lithic (stone) artifacts, usually comprised of fewer than 50 artifacts with few formal tools and no temporally or culturally diagnostic artifacts in the inventory. None of the sites has been listed on the *National Register of Historic Places*, but 150 are considered by DOE to be eligible for nomination as historic properties (see Table 3-21) based on National Register eligibility criteria. Several reports describe the specific procedures used to study and protect these cultural sites (DIRS 104807-CRWMS M&O 1995, all; DIRS 104810-CRWMS M&O 1995, all; DIRS 104813-CRWMS M&O 1995, all; DIRS 104814-CRWMS M&O 1995, all; DIRS 104818-CRWMS M&O 1995, all; DIRS 104819-CRWMS M&O 1995, all; DIRS 104822-CRWMS M&O 1995, all; DIRS 104824-CRWMS M&O 1995, all; DIRS 103198-YMP 1992, all). DIRS 104558-DOE (1988, all) describes how the Department meets its responsibilities under Section 106 of the National Historic Preservation Act and the American Indian Religious Freedom Act, and interactions with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer.

Table 3-21. Sites in the analyzed land withdrawal area potentially eligible for the *National Register of Historic Places.*

Type	Number
Temporary camps	43
Extractive localities	14
Processing localities	9
Localities	77
Caches	2
Stations	1
Historic sites	4
Total	***150***

This EIS separates archaeological sites into two broad groups, prehistoric and historic, separated by the first contact between American Indians and Euroamericans; in the Great Basin, this contact occurred in the early 1800s. The oldest prehistoric sites in southern Nevada are about 11,000 years old. These sites include one or more of the following features: temporary campsites, rock art, scattered lithic artifacts, quarries, plant-processing remains, hunting blinds, and rock alignments. The sites are categorized as temporary camps, extractive localities, processing localities, localities, caches, and stations. Historic sites include mining sites, ranching sites, transportation and communication sites, and some Cold War facilities. The following paragraphs define eligible types of sites at Yucca Mountain in each group (Table 3-21).

Temporary Camps. When occupied by a group of people, a temporary camp was a hub of activity for raw materials processing, implement manufacturing, and maintenance and general living activities. Camp artifacts typically include debris and discards from the making of stone tools, projectile points, bifacial stone tools, cores, milling stones, pottery, specialized tools, hearths, shelters, structures, and art. The nature and diversity of artifacts and features are the basis for designating a site as a temporary camp.

Extractive Localities. These were sites for specific extractive or resource-procurement tasks. They probably were occupied for short periods and for such limited activities as toolstone quarrying, hunting, and seed gathering. A single locality can contain isolated artifacts or large quantities of artifacts that reflect specific activities. In comparison to temporary camps, extractive localities have a low diversity of artifacts. Extractive locality artifacts include isolated projectile points or bifacial stone tools where hunting occurred, toolstone quarries with thousands of flakes, diffuse scatters of lithic flakes where plant materials were gathered, hunting blinds, and *tinajas* or water-catchment basins.

Processing Localities. Specific resource-processing tasks occurred at processing localities. These localities probably were occupied only for short periods and for limited activities such as butchering, milling, and roasting. A single site can contain an isolated artifact or large quantities of artifacts that reflect specific activities. Like extractive localities, processing localities have a low diversity of artifacts. Examples of processing localities include stone tool manufacturing stations, milling stations for processing food, diffuse scatters containing stone tools for processing meat and hides, hearths, and roasting pits.

Localities. This category includes sites that might have been either extractive or processing localities but for which there is not enough information to determine if such activities occurred.

Caches. Caches are temporary places for storing resources or artifacts. They include sealed rock shelters, rock piles, rock rings without evidence of habitation, rock alignments, brush piles held in place by rocks, and storage pits. A cache can also be an association of similar artifacts such as heat-treated bifacial stone tools, projectile points, and snares, or such resources as toolstone blanks and firewood in or on a natural feature such as at the base of a tree, in a rock shelter, or in a mountain saddle. Caches are distinguished from localities as places for storing resources, rather than as places of procurement or processing.

Stations. Stations are sites where groups gathered to exchange information about such things as game movement, routes of travel, and ritual activities. Examples of stations are rock cairns marking routes of travel, isolated petroglyphs and pictographs, geoglyphs, and observation points and overlooks.

Historic Sites. Historic sites are contemporaneous with or postdate the introduction of European influences in the region. Historic archaeological sites are few in number in the project area, usually represented by a small scatter of artifacts (cans and bottles). These short-term activities were related to mining, ranching, and transportation.

3.1.6.2 Native American Interests

3.1.6.2.1 *Yucca Mountain Project Native American Interaction Program*

In 1987, DOE initiated the Native American Interaction Program to consult and interact with tribes and organizations on the characterization of the Yucca Mountain site and the possible construction and operation of a repository. These tribes and organizations—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone people from Arizona, California, Nevada, and Utah—have cultural and historic ties to the Yucca Mountain area.

The Native American Interaction Program concentrates on the protection of cultural resources at Yucca Mountain and promotes a government-to-government relationship with the tribes and organizations. Its purpose is to help DOE comply with various Federal laws and regulations, including the American Indian Religious Freedom Act, the Archaeological Resources Protection Act, the National Historic Preservation Act, the Native American Graves Protection and Repatriation Act, DOE Order 1230.2 (*American Indian and Tribal Government Policy*), and Executive Orders 13007 (*Indian Sacred Sites*) and 13084 (*Consultation and Coordination with Indian Tribal Governments*). These regulations mandate the protection of archaeological sites and cultural items and require agencies to include Native Americans and Federally recognized tribes in discussions and interactions on major Federal actions.

Initial studies identified three tribal groups—Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone—whose cultural heritage includes the Yucca Mountain region (DIRS 104927-Stoffle 1987, p. 5-13). Additional ethnographic efforts eventually identified 17 tribes and organizations involved in the Yucca Mountain Project Native American and cultural resource studies. Figure 3-22 shows the traditional boundaries and locations of the 17 tribes and organizations.

Of the 17 tribal groups, 15 are Federally recognized tribes. The Pahrump Paiute Indian Tribe, which consists of a group of Southern Paiutes living in Pahrump, Nevada, has applied for Federal tribal recognition but to date has not received it. In addition, the Las Vegas Indian Center is not a Federally recognized tribe, but DOE included it in the Native American Interaction Program because it represents the urban Native American population of Las Vegas and Clark County, Nevada (DIRS 103465-Stoffle et al. 1990, p. 7).

The 17 tribes and organizations have formed the Consolidated Group of Tribes and Organizations, which consists of officially appointed tribal representatives who are responsible for presenting their respective tribal concerns and perspectives to DOE. The primary focus of this group has been the protection of cultural resources and environmental restoration at Yucca Mountain. Members of the group have participated in many ethnographic interviews and have provided DOE valuable insights into Native American cultural and religious values and beliefs. These interactions have produced several reports that record the regional history of Native American people and the interpretation of Native American cultural resources in the Yucca Mountain region (DIRS 104958-DOE 1989, pp. 30 to 74; DIRS 103465-Stoffle et al. 1990, pp. 11 to 25; DIRS 104959-DOE 1990, pp. 23 to 49). In addition, tribal representatives have identified and discussed traditional and current uses of plants in the area (DIRS 103464-DOE 1989, pp. 22 to 139).

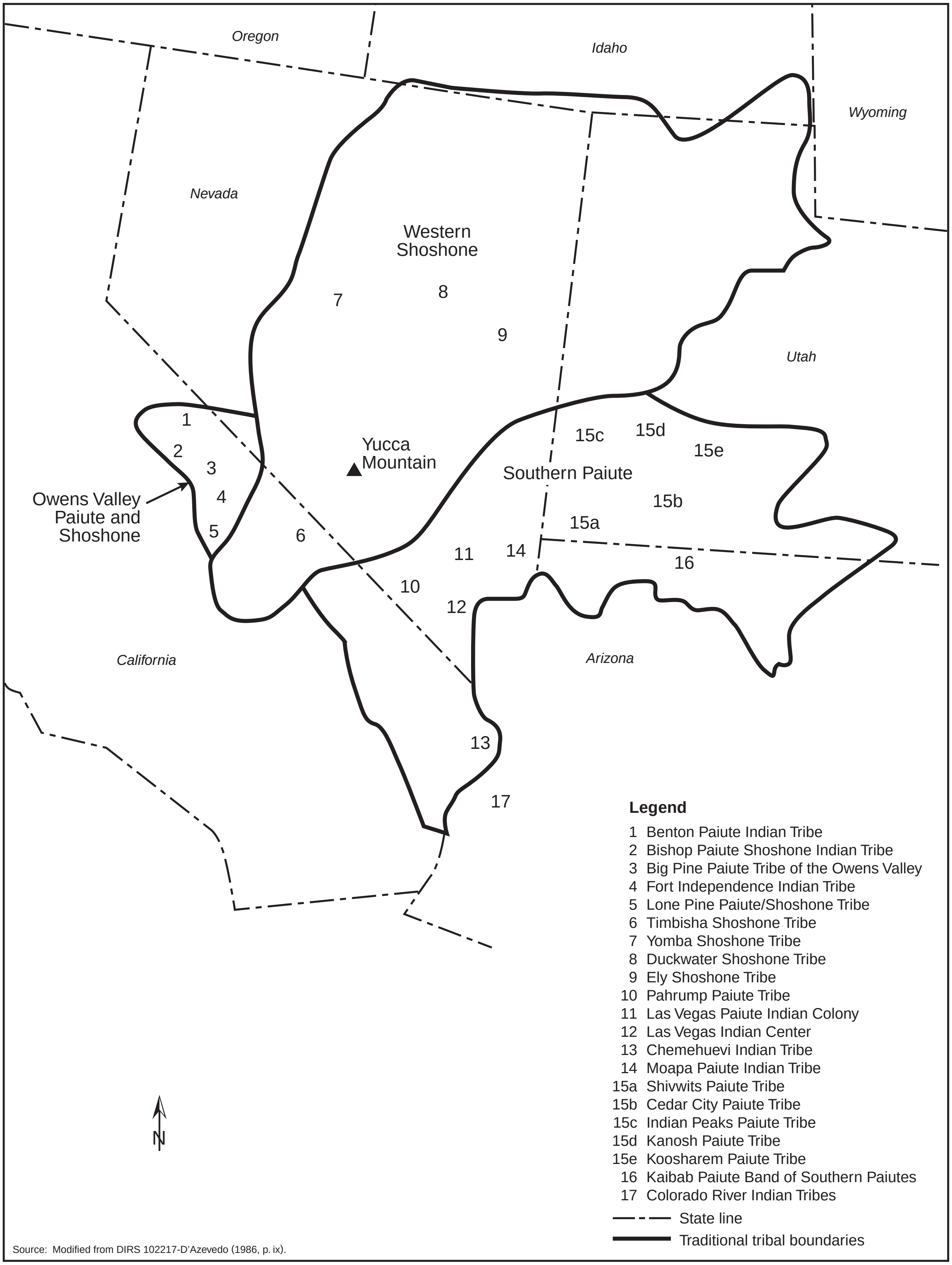

Figure 3-22. Traditional boundaries and locations of tribes in the Yucca Mountain region.

3.1.6.2.2 *Native American Views of Affected Environment*

During the EIS scoping process, DOE visited many tribes to encourage their participation. Members of the Consolidated Group of Tribes and Organizations designated individuals who represented the three tribal entities (Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone) to document their viewpoints on the Yucca Mountain area. This group, the American Indian Writers Subgroup, prepared a resource document that provides Native American perspectives on the repository (DIRS 102043-AIWS 1998, all). This report also describes the relationship between Native American people and DOE and discusses impacts of the Proposed Action while recommending impact mitigation approaches for reducing potential impacts to Native American resources and other heritage values in the Yucca Mountain region. In addition to the general and specific cultural resources issues, which are summarized in the following paragraphs, the report covers other critical topics, including concerns for occupational and public health and safety, environmental justice and equity issues, and social and economic issues. The report also provides recommendations for the conduct of appropriate consultation procedures for the repository and associated activities, and requests Native American participation in development of project resource management approaches to enable the incorporation of accumulated centuries of ethnic knowledge in long-term cultural resource protection strategies.

Native Americans believe that they have inhabited their traditional homelands since the beginning of time. Archaeological surveys have found evidence that Native Americans used the immediate vicinity of Yucca Mountain on a temporary or seasonal basis (DIRS 103465-Stoffle et al. 1990, p. 29). Native Americans emphasize that a lack of abundant artifacts and archaeological remains does not mean that their people did not use a site or that the land is not an integral part of their cultural ecosystem. Native Americans assign meanings to places involved with their creation as a people, religious stories, burials, and important secular events. The traditional stories of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples identify such places, including the Yucca Mountain area.

Native Americans believe that cultural resources are not limited to the remains of native ancestors but include all natural resources and geologic formations in the region, such as plants and animals and natural landforms that mark important locations for keeping their historic memory alive and for teaching their children about their culture. Equally important are the water resources and minerals in the Yucca Mountain region. Native Americans used traditional quarry sites to make tools, stone artifacts, and ceremonial objects; many of these sites are *power places* associated with traditional healing ceremonies. Despite the current physical separation of tribes from Yucca Mountain and neighboring lands, Native Americans continue to value and recognize the meaningful role of these lands in their culture and continued survival. Many areas in the Yucca Mountain region are important to them. Fortymile Canyon was an important crossroad where a number of traditional trails from such distant places as Owens Valley, Death Valley, and the Avawtz Mountain came together. Oasis Valley was an important area for trade and ceremonies. Native Americans believe that Prow Pass was an important ceremonial site and, because of this religious importance, have recommended that DOE conduct no studies in this area. Other areas are important based on the abundance of artifacts, traditional-use plants and animals, rock art, and possible burial sites.

According to Native Americans, the Yucca Mountain area is part of the holy lands of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples. Native Americans generally do not concur with the conclusions of archaeological investigators that their ancestors were highly mobile groups of aboriginal hunter-gatherers who occupied the Yucca Mountain area before Euroamericans began using the area for prospecting, surveying, and ranching. They believe that these conclusions overlook traditional accounts of farming that occurred before European contact. Yucca Mountain and nearby lands were central in the lives of the Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone peoples, who shared them for religious ceremonies, resource uses, and social events. Native Americans value the cultural resources in these areas, viewing them in a holistic manner. They believe that the water, animals, plants, air, geology, and artifacts are interrelated and dependent on each other for existence.

3.1.7 SOCIOECONOMICS

To define the existing conditions for the socioeconomic environment in the Yucca Mountain region, DOE determined the current economic and demographic status in a well-defined region (called the *region of influence*) near the site of the proposed repository. DOE based its definition of the socioeconomic region of influence on the distribution of the residences of current employees of the Department and its contractors who work on the Yucca Mountain Project or at the Nevada Test Site. The region of influence, therefore, consists of the three Nevada counties (Clark, Lincoln, and Nye Counties) where about 98 percent of the DOE 2001 workforce lives. The region of influence includes Lincoln County because of the possibility that DOE could build and operate an intermodal transfer station there. The Department used the residential distribution, which reflects existing commuting patterns, to estimate the future distribution of direct workers associated with the Proposed Action and the No-Action Alternative.

The socioeconomic region of influence for the Proposed Action, consisting of Clark, Lincoln, and Nye Counties in Southern Nevada, is shown in Figure 3-23. Clark County contains the City of Las Vegas and its suburbs. Based on a count of workers in a 1994 data report, 79 percent of the Yucca Mountain Project and Nevada Test Site onsite employees live in Clark County and approximately 19 percent live in Nye County (Table 3-22).

Table 3-22. Distribution of Yucca Mountain Project and Nevada Test Site employees by place of residence.[a]

Place of residence	Onsite workers	Percent of total
Clark County	1,268	79
Lincoln County	5	<1
Nye County	308	19
Total region of influence[b]	1,581	98
Outside region of influence	31	2
Total respondents[b]	***1,612***	***100.0***

a. Source: DIRS 104957-DOE (1994, Table 2-7).
b. Subtotals may not add to totals because of rounding.

DOE received numerous reports from affected units of local government providing socioeconomic baseline environmental information. In addition, DOE regularly requests and receives economic and demographic data from local and State of Nevada agencies. The data and reports contain information that characterizes the existing community environment, provides assessments of economic development, or includes basic economic and demographic trends. DOE reviewed these reports and incorporated pertinent information in this EIS.

DOE used the REMI Economic-Demographic Forecasting System model to estimate the baseline for population, employment, and three other economic measures: Gross Regional Product, real disposable income, and State and local government spending. The baseline was projected from 2000 to 2035 for the three counties in the Region of Influence, for the Rest of Nevada, and for all of Nevada. This baseline information is provided in Table 3-23. The REMI model was used to estimate changes to the socioeconomic measures from the baseline based on different cases for repository construction and operation and for different transportation options. These changes from the baseline are discussed in Chapters 4 and 6.

The version of the REMI model used for the Final EIS is based on historical data through 1997. This model was updated to include State of Nevada employment data for 1998. Additional local information was incorporated in the baseline projections. These included expected near-term changes and long-term stability in the mining industry in Nye County; changes in employment by DOE during 1999 and 2000; and expected increases in hotel-casino employment as a result of openings of new hotels and casinos through 2001. Finally, the baselines were adjusted to account for population estimates and projections made for Clark and Nye Counties and by the Nevada State Demographer’s Office.

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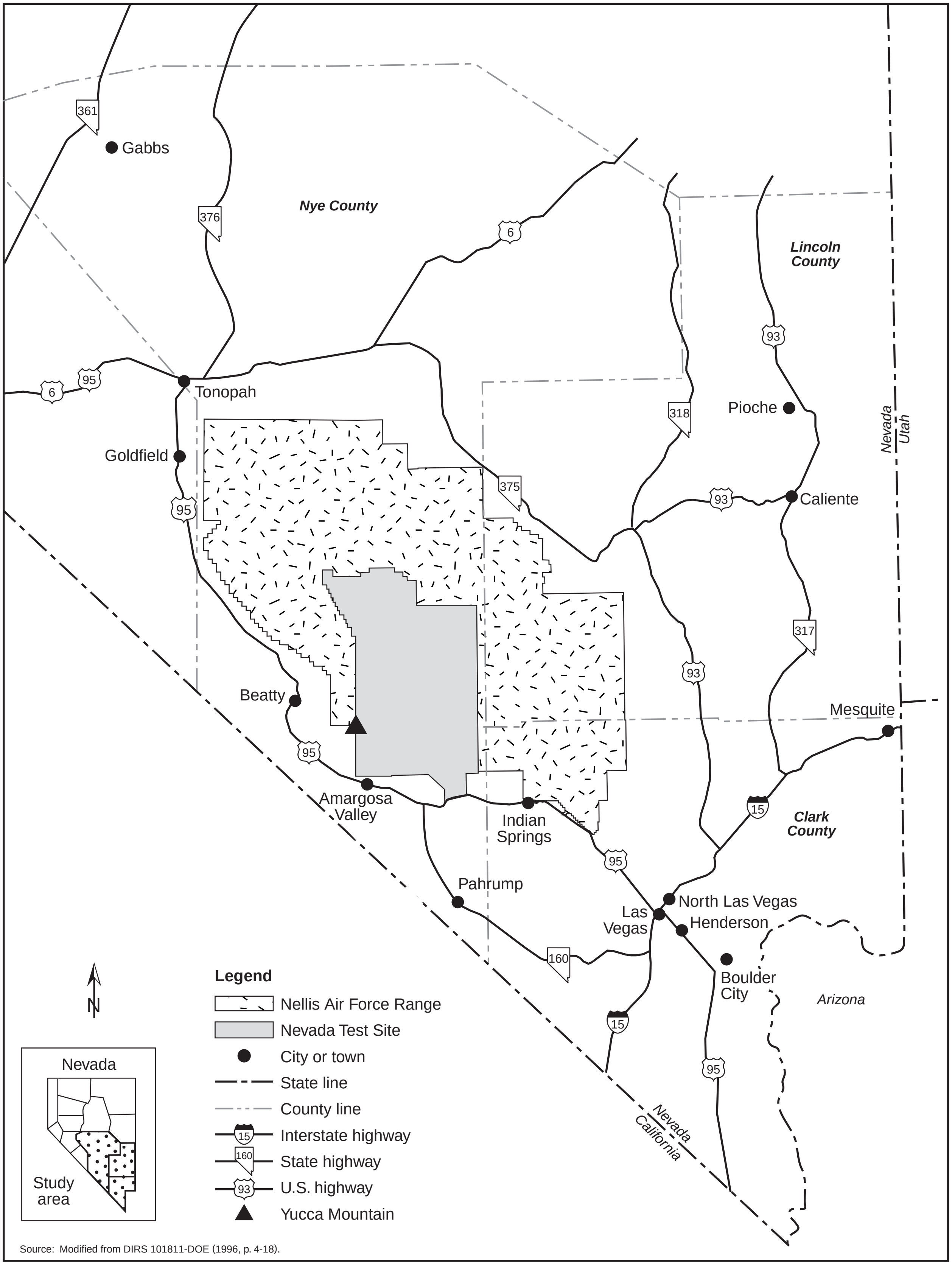

Figure 3-23. Socioeconomic region of influence.

Table 3-23. Baseline values for population, employment, and economic variables, 2000 to 2035.

Economic parameter	2000	2005	2010	2015	2020	2025	2030	2035
Population[a]								
Clark County	1,383,113	1,633,935	1,836,548	2,017,067	2,174,210	2,327,484	2,492,956	2,668,860
Nye County	40,656	49,387	56,759	62,641	67,351	72,047	76,952	82,417
Lincoln County	4,389	4,421	4,405	4,521	4,644	4,824	5,027	5,281
Rest of Nevada	598,047	645,720	690,171	753,120	814,231	872,195	929,565	992,999
All of Nevada	2,026,205	2,333,463	2,587,883	2,837,349	3,060,436	3,276,550	3,504,500	3,749,557
Employment[a]								
Clark County	830,265	909,842	980,618	1,045,289	1,099,697	1,151,187	1,211,596	1,283,384
Nye County	12,883	14,665	16,324	17,437	18,205	18,917	19,812	20,968
Lincoln County	2,249	2,419	2,527	2,612	2,664	2,732	2,835	2,987
Rest of Nevada	384,756	416,109	438,589	460,244	478,861	497,120	519,138	547,305
All of Nevada	1,230,153	1,343,035	1,438,058	1,525,582	1,599,427	1,669,956	1,753,381	1,854,644
Gross Regional Product[a,b,c]								
Clark County	45.3	50.2	55.7	61.1	66.1	71.3	77.5	84.7
Nye County	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3
Lincoln County	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Rest of Nevada	20.9	23.7	26.2	28.6	31.0	33.4	36.1	39.4
All of Nevada	66.9	74.9	82.9	90.8	98.3	106.0	114.9	125.6
Government Spending[a,b,c]								
Clark County	4.4	5.4	6.4	7.3	8.1	8.9	9.8	10.8
Nye County	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
Lincoln County	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rest of Nevada	2.1	3.3	3.7	4.1	4.6	5.0	5.4	6.0
All of Nevada	6.6	8.8	10.2	11.7	12.9	14.1	15.5	17.2
Real Disposable Income[a,b,c]								
Clark County	34.8	37.0	42.7	47.9	52.6	57.4	63.6	71.3
Nye County	0.6	0.8	0.9	1.1	1.2	1.2	1.4	1.5
Lincoln County	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rest of Nevada	16.5	16.9	18.9	20.9	22.8	24.8	27.3	30.1
All of Nevada	52.0	54.7	62.6	69.9	76.6	83.6	92.3	103.1

a. Values from State Demographer and Local Agencies' Baseline (DIRS 157089-TtNUS 2001, Appendix B, Attachments 5 to 10).
b. 2001 dollars, in billions.
c. Sums may not add to totals because of rounding.

Chapter 3 cites information, when available, from the 2000 Census as gathered by the Bureau of the Census. The analysis of impacts to socioeconomic parameters, including population and employment, in subsequent chapters are projected, however, from baselines developed with input from the State of Nevada and local sources.

Section 3.1.7.2 discusses employment estimates by industrial sectors by county in the region of influence.

3.1.7.1 Population

Southern Nevada has been and continues to be among the fastest-growing areas in the country. During the 1980s, the population of the region of influence had an average annual growth rate of 4.8 percent, with a total growth of 66.5-percent for the decade, adding more than 29,000 people annually and reaching 780,000 residents in 1990. In comparison to the State of Nevada, which had a growth of 50.1 percent between 1980 and 1990, the United States had a growth of less than 10 percent during the same period (DIRS 102119-Bureau of the Census 1995, all). This trend has continued during the 1990s. By 2000, the population of Clark County was about 1.4 million people. The region of influence grew by 88 percent from 1990 to 2000, averaging almost 65,000 new residents annually. In 2000, the estimated population

2000 CENSUS DATA AND UPDATED REMI MODEL

After issuing the Draft EIS and reviewing public comments on that document, DOE began revisiting its socioeconomic baseline projections and estimated impacts for the Final EIS utilizing data available from the State of Nevada and local communities. The revisions included an estimated baseline projection to 2035 for the socioeconomic parameters considered in the EIS.

In March 2001, while the preparation process for this Final EIS was under way, the Bureau of the Census released its county-level population data for Nevada based on its 2000 Census. In addition, DOE received a newly updated REMI model, with historical data through 1998. DOE then prepared an additional baseline projection, using the updated REMI model, for the Region of Influence, the Rest of Nevada, and the State of Nevada. This additional baseline incorporated State employment data for 1999, DOE employment for Nevada in 2000, expected additional hotel-casino employment due to an increase in the number of hotel rooms, expected near-term changes and long-term stability in the mining industry in Nye County, and population estimates and projections made for Clark and Nye Counties and by the Nevada State Demographer’s Office. The data was adjusted such that 2000 populations match the Decennial Census estimates. The census-anchored baseline was compared to the "local-based" forecast shown in Table 3-23. The census-anchored baseline and the percentage change from the State Demographer and Local Agencies' Baseline forecast for Nevada are listed below:

	Projected 2000 Census-anchored numbers by year, 2000 to 2035							
	2000	2005	2010	2015	2020	2025	2030	2035
Population[a]								
Clark County	1,375,766	1,685,159	1,892,536	2,068,053	2,233,042	2,378,426	2,550,975	2,743,684
Nye County	32,485	41,295	48,407	54,621	60,083	65,516	71,377	77,788
Lincoln County	4,165	4,178	4,192	4,328	4,532	4,717	4,888	5,062
Rest of Nevada	585,842	652,101	706,325	755,923	802,826	852,301	905,780	961,020
All of Nevada	1,998,258	2,382,733	2,651,460	2,882,925	3,090,483	3,300,960	3,533,020	3,787,554
Percent difference[b]	-1.38	2.11	2.46	1.61	0.98	0.74	0.81	1.01
Employment[a]								
Clark County	840,748	922,302	1,000,912	1,080,506	1,147,571	1,197,196	1,253,724	1,337,723
Nye County	13,001	14,947	16,824	18,360	19,592	20,594	21,771	23,465
Lincoln County	2,042	2,195	2,306	2,402	2,471	2,525	2,601	2,728
Rest of Nevada	384,364	412,141	437,244	463,337	483,473	497,075	514,505	543,526
All of Nevada	1,240,154	1,351,585	1,457,286	1,564,605	1,653,107	1,717,390	1,792,601	1,907,442
Percent difference[b]	0.81	0.64	1.34	2.56	3.36	2.84	2.24	2.85

a. Values from 2000 Census-Anchored Baseline (DIRS 157089-TtNUS 2001, Appendix C, Attachments 5 to 10)
b. Percent difference is for the Nevada (total) going from the State Demographer and Local Agencies' Baseline (Table 3-23) to the 2000 Census-Anchored Baseline shown above.

DOE also used the updated REMI model to estimate changes to the baseline for some of the repository design scenarios and transportation options to determine if the use of the revised model would provide meaningfully different estimates of changes in the economic and demographic measures. Sensitivity analyses revealed that the incremental differences between the two were generally small, and that differences in socioeconomic changes for analyzed scenarios and transportation options using the updated model were not meaningful.

DOE elected to base its socioeconomic projections and impact estimates in this Final EIS on the most recently available information from State and local resources, without consideration of the Decennial Census data, in consideration of the critiques received from commenters and for the following reasons:

- Analysis showed that the incremental differences or potential socioeconomic impacts associated with Yucca Mountain Repository activities are basically insensitive to the baseline used or which of the two versions of the model is used.
- The State of Nevada and local communities have not yet made available their independent estimates based on the 2000 Census data.
- There is some uncertainty involving what the final population totals would be for the Census data at the county level.

Similarly, DOE based its estimated population distribution and growth within 80 kilometers (50 miles) of the repository on projections to 2035 using the information from State and local sources. The 80-kilometer population distributions for 2000 and 2035 are shown in Figure 3-25.

of the region of influence was about 1.41 million people. Led by Clark County, Nevada is the fastest growing state in the country. From 1990 to 2000, Nevada had a total growth of 66.3 percent compared to the 13.1-percent overall growth of the United States.

Las Vegas and the immediate surrounding area dominate the Clark County population. The Las Vegas economy is driven by the growth of the hotel, amusement and recreation, and eating and drinking sectors associated with the gaming industry. As the popularity of gaming grew in the 1970s, 1980s, and 1990s, Las Vegas evolved as one of the country's major tourism and convention destinations. In 2000, Las Vegas hosted 35.8 million visitors, contributing $31.5 billion to the local economy (DIRS 155793-LVCVA 2001, all). The tourism trend is expected to continue well into this century. However, there are a number of economic indicators that suggest the growth in the gaming industry is slowing. The relatively moderate housing costs, temperate climate, abundance of recreational opportunities, favorable business conditions, and absence of a State income tax have contributed to commercial and residential growth. The number of retirees (from across the United States) moving to communities in the region of influence is escalating.

Nye County, which has been the site of booms and busts due to fluctuating mining activity and the recent decline of Nevada Test Site employment, is home to approximately 4 percent of the Yucca Mountain Project employees who work in Nevada (DIRS 155987-DOE 2001, Tables 3-14 and 3-22). Pahrump, in southern Nye County, is experiencing growth caused primarily by inmigrating retirees and its proximity to Las Vegas. In 2000, Nye County had about 32,500 residents, having experienced an 82.7-percent growth in the 1990s. The 2000 population in Lincoln County was about 4,200, up from about 3,800 in 1990, a growth of approximately 10.3 percent.

Although the annual growth rate of the region of influence is likely to slow from the extraordinary pace of the 1990s, the population should continue to grow at a rate of 2 to 4 percent a year in this decade. Clark County will continue to lead the population growth in the foreseeable future in the region of influence.

The region of influence includes a number of incorporated cities and towns as well as unincorporated communities (Table 3-24). The largest city in Clark County is Las Vegas, followed by Henderson. In 2000, Las Vegas had a population of about 480,000 compared to Henderson, which had about 180,000 residents. Nye County has no incorporated cities, but the largest community is unincorporated Pahrump, which had an estimated population of about 25,000 in 2000. Lincoln County has only one incorporated city, Caliente, which is the largest community with a 2000 population of about 1,100.

Clark County has a population density of about 140 persons per square mile. Lincoln County has approximately 0.4 person per square mile, and Nye County has a population density of about 1.4 persons per square mile.

Population growth in the State of Nevada and Clark County is expected to exceed average national trends through 2035. The explosive population growth in Clark County is expected to slow, but remain well above national averages, at about 3 percent through 2035. Clark County will continue to house approximately 97 percent of the population in the region of influence. Nye County is also expected to grow at an accelerated rate, with an average annual increase of approximately 2 percent to 2035. Lincoln County is expected to experience less than 1-percent annual growth through the first third of this century. Figure 3-24 shows estimated populations for the region of influence and the State of Nevada, projected out to 2035.

3.1.7.2 Employment

Of the three counties that comprise the region of influence, Clark County has by far the largest economy; in 2000, the estimated employment was about 840,000. This constituted 98 percent of the regional

Table 3-24. Population of incorporated cities and selected unincorporated towns, 1991 to 2000.[a]

Jurisdiction	1991[b]	1995[b]	2000[c]
Clark County			
Boulder City	13,000	14,000	15,000
Henderson	77,000	120,000	180,000
Indian Springs[d]	N/A[e]	N/A	1,300
Las Vegas	290,000	370,000	480,000
Mesquite	2,100	5,100	9,400
North Las Vegas	51,000	78,000	120,000
Nye County			
Amargosa Valley[d]	920	1,200	1,200
Beatty[d]	1,800	1,900	1,200
Gabbs[d,f]	680	360	320
Pahrump[d]	8,800	15,000	25,000
Tonopah[d]	3,600	3,400	2,600
Lincoln County			
Caliente	1,100	1,200	1,100

a. Population numbers have been rounded to two significant figures.
b. Sources:
   (1) DIRS 100065-NSDO (1998, all).
   (2) DIRS 148031-PIC (1993, all).
   (3) DIRS 148060-Levy (1997, all).
   (4) DIRS 153928-NDA (2000, all).
c. Source: DIRS 155872-Bureau of the Census (2000, place totals).
d. Selected unincorporated towns.
e. N/A = not available.
f. Gabbs unincorporated in May 2001.

employment and about 68 percent of the State employment. During the same year Nye County had an employment base of about 13,000, and the Lincoln County employment base was about 2,000. Clark County should continue to lead employment growth in the region of influence.

Between 1980 and 1990, Clark County added an average of 19,000 jobs a year (Table 3-25). Since 1990 that pace has increased to more than 38,000 new jobs a year. *Total employment* increased 35 percent between 1990 and 1995, adding about 160,000 jobs. In 2000, Clark County added 3,000 jobs a month to its labor force. The services sector, which includes hotels, eating and drinking establishments, and amusement and recreation facilities, is the largest employer in Clark County, representing 45 percent of the employment in 2000.

Although Nye County's employment increased between 1980 and 1990, it declined to about 11,000 in 1995, a decrease of 15 percent (Table 3-26). Employment rebounded and by 2000 there were approximately 13,000 jobs in the county. Services represents the largest employment sector in the Nye County economy. In 2000, services comprised 43 percent of Nye County's employment and retail trade made up an additional 14 percent. Lincoln County's employment declined between 1990 and 1995 after growth during the 1980s (Table 3-27). Employment had declined to about 2,000 positions by 2000. As in Clark and Nye Counties, services represented the largest sector of the Lincoln County economy, about 35 percent. Employment in Federal, State, and local government agencies represented a significant presence in the County's employment, about 29 percent.

Las Vegas, in Clark County, has one of the fastest growing economies in the country. The rapid growth of the Las Vegas area is driven by the gaming and tourism industry. For each hotel room constructed, an employment multiplier effect creates an estimated 2.5 direct and indirect (composite) jobs. About 4,200 hotel rooms were added in 2000 alone. Despite an inventory of more than 124,000 rooms, hotels consistently operate at 90 percent occupancy, reaching 97 percent on weekends.

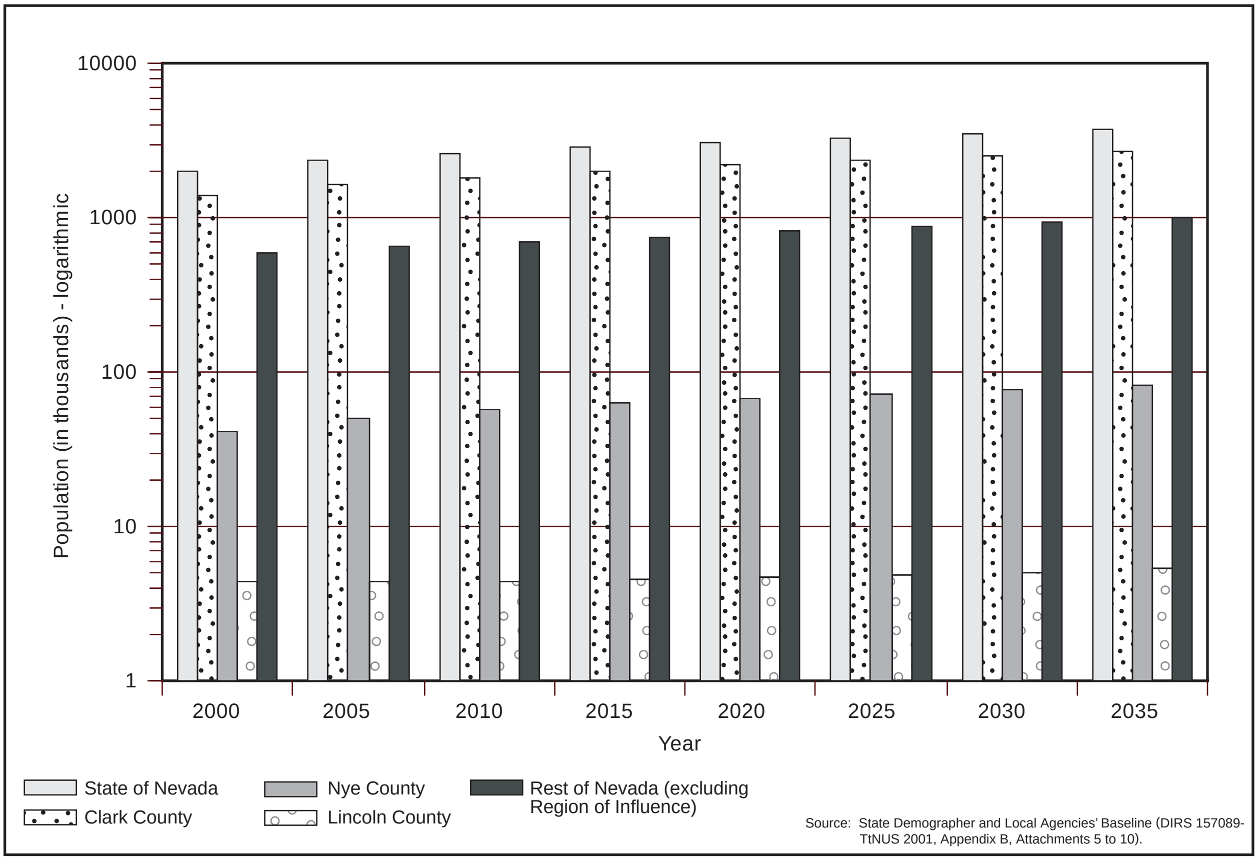

Figure 3-24. Estimated populations to 2035 for the region of influence and the State of Nevada.

Hundreds of new jobs are added to the regional economy each month, and many job seekers have come to the area (primarily Clark County). Some of these new arrivals, however, lack the necessary job skills or experience that area employers require. As a result, Clark County has maintained a healthy, relatively low unemployment rate, but one that remains near State and national averages. In 2000, Clark and Nye Counties had unemployment rates of 4.3 percent and 5.4 percent, respectively (DIRS 155818-NDETR 2001, all). The average in the State of Nevada was about 4.4 percent, and nationwide the unemployment rate was about 4.0 percent. Lincoln County had an unemployment rate above the national average at 6.6 percent (DIRS 155818-NDETR 2001, all). Onsite employment levels at the Exploratory Studies Facility remained relatively constant between 1995 and 2000, and are not likely to fluctuate substantially through the end of site characterization activities.

In 2000, an average of about 2,320 workers (220 work on the site and 2,100 off the site) worked on the Yucca Mountain Project. Most offsite workers are employed in the Las Vegas area (DIRS 155987-DOE 2001, Table 3-1).

As would be expected, projected employment in the region of influence broadly reflects population trends. The number of jobs in Clark County will reach approximately 1.3 million in 2035, up from 840,000 in 2000. Clark County will host 98 percent of the employment opportunities in the three-county region of influence. Nye County will add approximately 10,000 additional workers by 2035 from the 13,000 base in 2000. Lincoln County employment will expand from 2,040 in 2000 to approximately 2,700 in 2035.

Table 3-25. Clark County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	1,300	3,900	6,200	9,400
Mining	590	820	1,200	1,500
Construction	16,000	41,000	53,000	81,000
Manufacturing	7,300	12,000	18,000	21,000
Transportation and public utilities	14,000	21,000	29,000	38,000
Wholesale trade	6,500	14,000	19,000	25,000
Retail trade[d]	44,000	72,000	98,000	134,000
Finance, insurance, and real estate	20,000	32,000	44,000	62,000
Farms	420	400	300	350
Services[d]	120,000	210,000	290,000	374,000
Government				
Federal Government - civilian	4,800	6,900	7,800	8,100
Federal Government - military	11,000	11,000	9,500	10,000
State and local government	22,000	33,000	45,000	66,000
Totals[e]	***268,000***	***458,000***	***621,000***	***830,000***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are included in Retail Trade.
e. Sums may not add to totals because of rounding.

Table 3-26. Nye County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	50	70	110	110
Mining	1,100	2,000	1,400	830
Construction	410	390	560	880
Manufacturing	88	160	250	310
Transportation and public utilities	210	280	280	400
Wholesale trade	25	49	100	180
Retail trade	530	960	1,200	1,800
Finance, insurance, and real estate	360	290	450	510
Farms	220	260	210	260
Services[d]	4,100	7,700	5,200	5,300
Government				
Federal Government - civilian	130	200	200	200
Federal Government - military	100	77	53	81
State and local government	540	930	1,200	2,000
Totals[e]	***7,860***	***13,400***	***11,200***	***12,900***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are included in Retail Trade.
e. Sums may not add to totals because of rounding.

Table 3-27. Lincoln County employment by sector, 1980 to 2000.[a]

Sector	1980[b]	1990[b]	1995[b]	2000[c]
Private sector				
Agriculture, forestry, and fisheries	4	30	22	23
Mining	310	30	18	51
Construction	75	47	44	32
Manufacturing	12	10	10	19
Transportation and public utilities	96	88	62	120
Wholesale trade	12	10	17	42
Retail trade	310	250	270	380
Finance, insurance, and real estate	51	47	68	77
Farms	160	180	150	160
Services[d]	380	1,200	869	680
Government				
Federal Government - civilian	25	45	39	36
Federal Government - military	12	12	8	11
State and local government	360	480	560	620
Totals[e]	***1,860***	***2,430***	***2,140***	***2,250***

a. Employment numbers have been rounded to two significant figures; totals to three significant figures.
b. Source: DIRS 155983-BEA (1998, all).
c. Source: DIRS 157089-TtNUS (2001, Appendix B, Attachments 5 to 10).
d. Service sector includes hotels, amusement and recreation. Eating and drinking employment are contained in Retail Trade.
e. Sums may not add to totals because of rounding.

The 1997 per-capita income of Clark County was about $26,200, near the State's average of about $26,600. The per-capita income in Nye County was $20,400 and in Lincoln County it was $18,400. The U.S. average was $25,300 in the same year (DIRS 155987-DOE 2001, Tables: 1994-1998 Per Capita Income, Nevada vs. Western States; 1970-1998 Total & Per Capita Income in Nevada; and 1989-1997 Per Capita Income in Nevada, by County).

3.1.7.3 Payments-Equal-to-Taxes

Another issue of interest is the DOE Payments-Equal-To-Taxes Program. Section 116(c)(3)(A) of the Nuclear Waste Policy Act, as amended, requires the Secretary of Energy to "…grant to the State of Nevada and any *affected unit of local government* an amount each *fiscal year* equal to the amount such State or affected unit of local government, respectively, would receive if authorized to tax site characterization activities…." The Yucca Mountain Site Characterization Office is responsible for implementing and administering this program for the Yucca Mountain Project. DOE acquired data from the project organizations that purchase or acquire property for use in Nevada, have employees in Nevada, or use property in Nevada. These organizations include Federal agencies, national laboratories, and private firms. Not all of them have a Federal exemption, so they pay the appropriate taxes. The purchases (sales and use tax), employees (business tax), and property (property or possessory use taxes) of the Yucca Mountain Project organizations that exercise a Federal exemption are subject to the Payments-Equal-To-Taxes Program (DIRS 156763-YMP 2001, all).

The actual sales and use taxes, property taxes, and Nevada business taxes paid by Yucca Mountain Project organizations that are not exempted from tax payment obligations for May 1986 through June 2000 have been totaled. These organizations paid sales or use taxes of $2.5 million for purchases consumed in Clark County and $5.1 million in Nye County, paid property or possessory taxes of about $90,000 in Clark County and $37,000 in Nye County, and paid Nevada business taxes of about $810,000 (DIRS 156763-YMP 2001, all).

The Payments-Equal-To-Taxes for sales or use taxes from May 1986 through June 2000 was about $4.4 million for purchases consumed in Clark County and $450,000 in Nye County. For property taxes it was about $940,000 in Clark County, $46 million in Nye County, $8,000 in Lincoln County, and $3,700 in Esmeralda County. For Nevada business taxes (Clark, Nye, Esmeralda, and Lincoln Counties), about $160,000 was paid (DIRS 156763-YMP 2001, all).

3.1.7.4 Housing

Spurred by the rapid population growth and soaring employment opportunities, the residential housing market is strong and steady in the Las Vegas area. From 1992 to 1996, annual sales of new homes exceeded 16,000 units. In 1999, a record 21,200 units were sold. In 2000, 20,500 new homes and 29,500 existing homes were sold. More than 400 residential developers sell properties in the Las Vegas area, leading to a highly competitive market. The competitive environment has kept price increases to the rate of inflation. Eighty-five percent of the new homes sold were priced between $100,000 and $200,000. In 2000, the median price of a new home was about $160,000 and the median price of a resale home was about $132,000. These sale prices are slightly below the national median prices of $165,000 for new homes and $143,500 for existing units. Large master-planned communities are common, and average about 30 percent of the total home sales. Steady employment and population growth should continue to spur demand for housing. Sustained growth will depend on further development of large-scale resort and gaming projects.

The housing stock of Clark County in 1990 was about 320,000 units, which consisted of about 157,000 single-family units, 130,000 multifamily units, and 33,000 mobile homes or other accommodations. About 290,000 of these units were occupied (DIRS 148097-Bureau of the Census 1998, all) resulting in 2.5 persons per household. The number of households in Clark County in 2000 was about 560,000 units (DIRS 155872-Bureau of the Census 2000, all).

The housing stock of Nye County in 1990 was about 8,100 units, which consisted of about 2,300 single-family units, 560 multifamily units, and 5,200 mobile homes or other accommodations. About 6,700 of these units were occupied, resulting in 2.5 persons per household (DIRS 148097-Bureau of the Census 1998, all). The number of households in Nye County in 2000 was about 15,900 (DIRS 155872-Bureau of the Census 2000, all).

The housing stock of Lincoln County in 1990 was about 1,800 units, which consisted of about 1,000 single-family units, 160 multifamily units, and 600 mobile homes or other accommodations. About 1,300 of these units were occupied, resulting in 2.6 persons per household (DIRS 148097-Bureau of the Census 1998, all). The number of households in Lincoln County in 2000 was about 2,200 (DIRS 155872-Bureau of the Census 2000, all).

Because most population and employment growth in the region of influence will occur in Clark County, most housing growth also will occur there. The only other area in the region likely to see large growth is Pahrump in southern Nye County. Housing changes in Lincoln County probably will be minimal in the foreseeable future.

3.1.7.5 Public Services

Education. In the 2000-2001 school year, the region of influence contained about 223 public elementary and middle schools, 37 public high schools, 13 alternative schools, 4 special education schools, an Advanced Technology Academy, an adult education center, and 3 charter schools (DIRS 157141-NDE 2001, all). Clark County opened 11 of these schools in the 2000-2001 school year. The average pupil-teacher ratio was about 21-to-1 for elementary schools and 19-to-1 for secondary schools (DIRS 157142-NDE 2001, all). In 1999, the national pupil-teacher ratio was about 19-to-1 for elementary schools and

15-to-1 for secondary schools (DIRS 155819-NCES 2000, all). Clark County has the tenth-largest school district in the country; during the 2000-2001 school year, Clark County had about 258 schools and nearly 232,000 students (Table 3-28). During the same period, Nye County had approximately 5,300 students, and Lincoln County had about 1,020 students (DIRS 155820-NDE 2001, all).

Table 3-28. Enrollment by school district and grade level.[a,b]

District	Actual 1996-1997[c]	Actual 2000-2001[d]
Clark County		
Prekindergarten	1,100	1,100
Kindergarten	15,000	19,000
Elementary (grades 1-6)	90,000	120,000
Secondary (grades 7-12)	73,000	94,000
District totals[e]	179,000	232,000
Nye County		
Prekindergarten	43	54
Kindergarten	370	360
Elementary (grades 1-6)	2,300	2,500
Secondary (grades 7-12)	2,200	2,300
District totals[e]	4,970	5,290
Lincoln County		
Prekindergarten	22	15
Kindergarten	57	62
Elementary (grades 1-6)	400	370
Secondary (grades 7-12)	630	570
District totals[e]	1,110	1,020

a. Figures include ungraded students who are enrolled in school for special education and students who cannot be assigned to a grade because of the nature of their conditions; Prekindergarten refers to 3- and 4-year-old minors receiving special education.
b. Enrollment numbers have been rounded to two significant figures; totals to three significant figures.
c. Source: DIRS 157146-NDE (2001, all).
d. Source: DIRS 155820-NDE (2001, all).
e. Totals might not equal sums of values due to rounding.

Health Care. Health care services in the region of influence are concentrated in Clark County, particularly in the Las Vegas area. In 2000, Clark County had nine community hospitals (DIRS 156286-Medical Central Online 2001, all), including the newly opened 141-bed Siena campus of St. Rose Dominican (DIRS 156288-Babula 2000, all) and several specialized care facilities. Several major health care providers have proposed new hospitals or expansions of existing facilities and are awaiting various approval processes. Voters rejected a proposed Children's Hospital in June 2001. Although Nye County has one hospital in Tonopah, most people in the southern part of the county use local clinics or go to hospitals in Las Vegas. Lincoln County has one hospital in Caliente (DIRS 156286-Medical Central Online 2001, all). Table 3-29 lists hospital use in the region of influence.

Medical services are available at the Nevada Test Site for Exploratory Studies Facility personnel; these services include two paramedics and an ambulance in Area 25. Backup services are on call from other Test Site locations. In addition, the Nevada Test Site provides medical services for Yucca Mountain Project workers at a clinic in Mercury, which has no overnight capability. When patients need urgent care, the Yucca Mountain Project relies on the helicopter "Flight for Life" and "Air Life" operations from Las Vegas. In emergencies, Area 25 can call on Nellis Air Force Base or Nye County for help.

Law Enforcement. The Las Vegas Metropolitan Police Department is responsible for law enforcement in Clark County with the exceptions of the Cities of North Las Vegas, Henderson, Boulder City, and Mesquite, which have their own police departments. The Las Vegas police department is the largest law enforcement agency in Nevada; in 2001, it had about 2,620 employees including 1,750 commissioned officers; a ratio of about 2.5 employees or 1.6 commissioned officers per 1,000 residents. In 2000, the Nye County Sheriff Department had 113 employees, a ratio of 3.5 employees per 1,000 residents, and Lincoln County had 17 sheriff department employees serving an area of 27,500 square kilometers (10,600 square miles), a ratio of 4.0 employees per 1,000 residents. In comparison, the national officer-to-population ratio is 2.4 officers per 1,000 residents, (DIRS 148129-FBI 1996, pp. 1 to 3).

Table 3-29. Hospital use by county in the region of influence.[a]

County	1995[b]	1998	2000
Clark			
Population	1,000,000	1,260,000[c]	1,380,000[d]
Average number of beds	2,100	2,400[e]	2,600[f,g,h]
Beds per 1,000 residents	2.2	1.9[f]	1.9[e]
Patient-days	530,000	607,000[c]	N/A
Nye			
Population	24,000	29,700[c]	32,000[d]
Average number of beds	21	10[e]	42[f,g]
Beds per 1,000 residents	0.86	0.33[f]	1.3
Patient-days	1,900	560[e]	N/A
Lincoln			
Population	3,900	4,200[c]	4,200[d]
Average number of beds	4	4[e]	20[f,g]
Beds per 1,000 residents	1.0	0.95[f]	4.8
Patient-days	360	300[e]	N/A

a. All displayed numbers have been rounded to two or three significant figures.
b. Source: DIRS 103451-Rodefer et al. (1996, pp. 214 to 216).
c. Source: DIRS 153928-NDA (2000, all).
d. Source: DIRS 155872-Bureau of the Census (2000, County totals).
e. Average number of beds and patient days (DIRS 155910-State of Nevada 1999, all).
f. DIRS 156286-Medical Central Online (2001, all).
g. Actual, staffed number of beds.
h. DIRS 156288-Babula (2001, all).

Protection. A combination of fire departments provides protection in the region of influence; these include the Clark County, Las Vegas, and North Las Vegas fire departments and several other city, county, and military departments. In 2001, the Clark County Fire Department had about 500 paid and 390 volunteer firefighters. The Las Vegas Fire Department had 334 paid firefighters and the North Las Vegas Fire Department had 259 firefighters. In 2001, Nye County and Lincoln County met fire suppression needs with volunteers from the individual communities in the counties. The national average is 4.1 firefighters (paid and volunteer) per 1,000 residents.

3.1.8 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The public health and safety region of influence consists of the number of persons residing within an 80-kilometer (50-mile) radius of the repository site at the end of site characterization. The estimated population in 2000 is about 34,000, which could grow to an estimated 76,000 by 2035. Both the population estimate for 2000 and the projection for 2035 are based on the State Demographer and Local Agencies' Baseline as described in Section 3.1.7, and are distributed over the 80-kilometer (50-mile) radius as shown in Figure 3-25. The region of influence includes parts of Nye, Clark, Lincoln, and Esmeralda Counties in Nevada, as well as Inyo County in California (Figure 3-25). Potentially affected workers include those at the repository site and at nearby Nevada Test Site facilities. This section describes the existing radiation environment and the baseline cancer incidence in the region of influence. Unless otherwise noted, the *Environmental Baseline File for Human Health* (DIRS 104544-CRWMS M&O 1999, all) is the basis of the information in this section.

Section 3.1.8.1 describes the various radiation sources that make up the radiation environment. Section 3.1.8.2 describes the existing radiation environment in the Yucca Mountain region. Section 3.1.8.3 describes the health-related mineral issues encountered during site characterization activities. Section 3.1.8.4 describes the worker industrial safety experienced from site characterization activities.

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County	1995[b]	1998	2000
Clark			
Population	1,000,000	1,260,000[c]	1,380,000[d]
Average number of beds	2,100	2,400[e]	2,600[f,g,h]
Beds per 1,000 residents	2.2	1.9[f]	1.9[e]
Patient-days	530,000	607,000[c]	N/A
Nye			
Population	24,000	29,700[c]	32,000[d]
Average number of beds	21	10[e]	42[f,g]
Beds per 1,000 residents	0.86	0.33[f]	1.3
Patient-days	1,900	560[e]	N/A
Lincoln			
Population	3,900	4,200[c]	4,200[d]
Average number of beds	4	4[e]	20[f,g]
Beds per 1,000 residents	1.0	0.95[f]	4.8
Patient-days	360	300[e]	N/A

a. All displayed numbers have been rounded to two or three significant figures.
b. Source: DIRS 103451-Rodefer et al. (1996, pp. 214 to 216).
c. Source: DIRS 153928-NDA (2000, all).
d. Source: DIRS 155872-Bureau of the Census (2000, County totals).
e. Average number of beds and patient days (DIRS 155910-State of Nevada 1999, all).
f. DIRS 156286-Medical Central Online (2001, all).
g. Actual, staffed number of beds.
h. DIRS 156288-Babula (2001, all).

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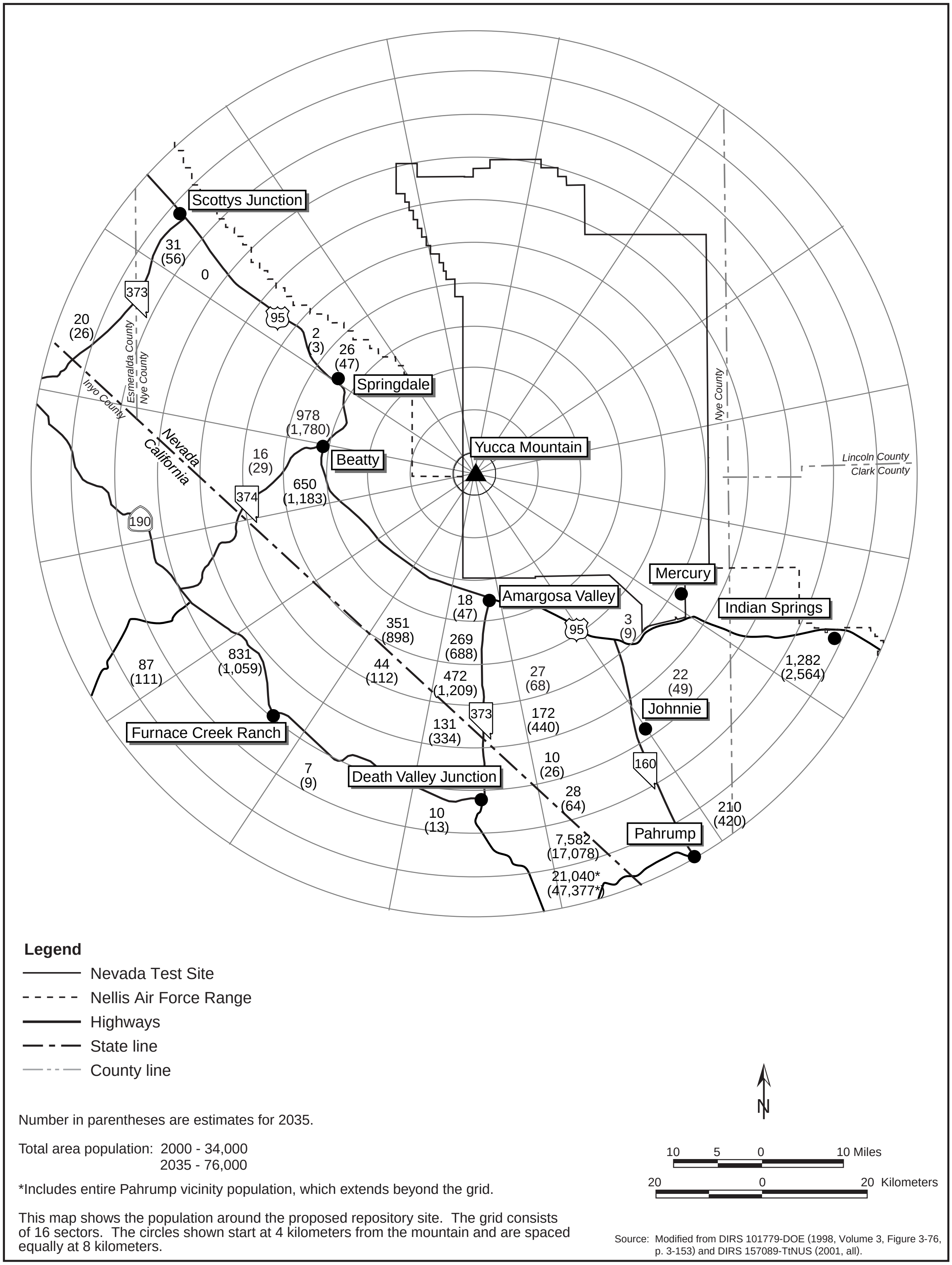

Figure 3-25. Population distribution within 80 kilometers (50 miles) of the proposed repository site, 2000 estimate and 2035 projection (in parentheses), based on the State Demographer and Local Agencies' Baseline.

3.1.8.1 Radiation Sources in the Environment

Types of Radiation. There are ambient levels of radiation at and around the site of the proposed repository just as there are around the world. All people are inevitably exposed to the three sources of *ionizing radiation*: those of *natural* origin unaffected by human activities, those of natural origin but affected by human activities (called *enhanced natural* sources), and *manmade* sources. Natural sources (natural background radiation) include *cosmic radiation* from space, *cosmogenic radionuclides* produced when cosmic radiation interacts with matter in the atmosphere or ground, and naturally occurring, long-lived primordial radionuclides in the Earth's mantle. Enhanced natural sources include those that can increase exposure as a result of human actions, deliberate or otherwise. For example, a mill tailings pile from a uranium extraction process probably would contain concentrated levels of naturally occurring radionuclides. A variety of radiation exposures, generally smaller than those caused by natural sources, result from manmade sources including nuclear medicine, medical *X-rays*, and consumer products.

Natural background radiation is the largest contributor to the average radiation dose of individuals. The natural occurrence of cosmic radiation, cosmogenic radionuclides, and primordial radionuclides varies throughout the world depending on such factors as altitude and geology. External radiation comes from all three of these natural sources, but cosmic radiation and radiation from primordial radionuclides are the largest dose contributors. Cosmic radiation consists of charged particles (primarily protons from extraterrestrial sources) that have sufficiently high energies to generate secondary particles that have direct and indirect ionizing properties. The three main primordial radionuclide contributors to external terrestrial gamma radiation are potassium-40 and the members of the thorium and uranium decay series. Most external terrestrial gamma radiation comes from the top 20 centimeters (8 inches) of soil, with a small contribution from airborne radon decay products. Although of smaller importance to natural external dose than the other two mechanisms, two cosmogenic radionuclides, sodium-22 and beryllium-7, produce quantifiable external doses in humans.

Internal radiation dose from natural sources comes primarily from the primordial radionuclides and their decay products. The largest individual source of internal dose comes from the inhalation of radon-222 and its decay products, which are all members of the uranium-238 decay series. This exposure comes mainly from inhalation of these radionuclides in indoor air, coming from the soil underneath buildings. All of the primordial radionuclides are in the body in various concentrations, incorporated by ingesting or inhaling these radionuclides in air, water, and all types of food products. In addition, two cosmogenic radionuclides—tritium (hydrogen-3) and carbon-14—produce quantifiable internal doses. Table 3-30 lists estimated radiation doses from natural sources to individuals in the region of influence and other locations in the United States.

Effects of Radiation Exposure. The effect of radiation on people depends on the kind of radiation exposure (alpha and beta particles, and X-rays and gamma rays), the total amount of tissue exposed to radiation, and the duration of the exposure. The amount of radiant energy imparted to tissue from exposure to ionizing radiation is referred to as *absorbed dose*. The sum of the absorbed dose to each tissue, when multiplied by certain quality and weighting factors that take into account radiation quality and different sensitivities of the various tissues, is referred to as *effective dose equivalent* and is expressed in *rem*. The Code of Federal Regulations contains further discussion of DOE radiation protection standards and methods of dose assessment (10 CFR Part 835).

An individual can be exposed to radiation from outside or inside the body because radioactive materials can enter the body by ingestion or inhalation. External dose is different from internal dose in that it is delivered only during the actual time of exposure. An internal dose, however, continues to be delivered as long as the radioactive source is in the body (although both radioactive decay and elimination of the radionuclide by ordinary metabolic processes usually decrease the *dose rate* with the passage of time).

TERMS USED IN RADIATION DOSE ASSESSMENT

Curie: A unit of radioactivity equal to 37 billion disintegrations per second; also a quantity of any nuclide or mixture of nuclides having 1 curie of radioactivity.

Picocurie per liter (or gram): A unit of concentration measure describing the amount of radioactivity (in picocuries) in a volume (or mass) of a given substance [typically, air or water (by volume) or soil (by mass)]. A picocurie is one one-trillionth of a curie.

Rad: The unit of absorbed radiation dose in terms of energy. One rad is equal to an absorbed dose of 100 ergs per gram.

Rem: The unit of effective dose equivalent from ionizing radiation to the human body. It is used to express the amount of radiation to which a person has been exposed. The effective dose equivalent in rem is equal to the absorbed dose in rad multiplied by quality and weighting factors that are necessary because biological effects can vary both by the type of radiation (even of the same deposited energy) and by the specific tissue exposed.

Total effective dose equivalent: Often generically referred to simply as dose, it is an expression of the radiation dose received by an individual from external radiation and from radionuclides internally deposited in the body. All doses presented in this document are in terms of total effective dose equivalent.

Latent cancer fatality: A death resulting from cancer that has been caused by exposure to ionizing radiation. There is typically a latent period between the time of radiation exposure and the time the cancer cells become active.

Table 3-30. Radiation exposure from natural sources (millirem per year).[a]

	Annual dose (effective dose equivalent)					
					Region of influence	
Source	U.S. average	Aiken[b]	Oak Ridge[c]	Las Vegas	Amargosa Valley	Beatty
Cosmic and cosmogenic	28	29	36	(d)	40	(d)
Terrestrial	28	24	51	89	56	150
Radon in homes (inhaled)[e]	200	200	200	200	200	200
In body	40	40	40	40	40	40
Totals[f]	***300***	***290***	***330***	***330***	***340***	***390***

a. Sources: DIRS 146592-Black and Townsend (1998, p. 4-31); DIRS 103208-DOE (1995, p. 4-211 and 4-394) DIRS 103207-DOE (1995, Figure 3-16); DIRS 101855-NCRP (1987, Section 2); DIRS 153135-DOE (1999, p. A-9).
b. Aiken, South Carolina, is the location of the DOE Savannah River Site.
c. Oak Ridge, Tennessee, is the location of the DOE Oak Ridge Reservation.
d. Included in the terrestrial source.
e. Value for radon is an average for the United States.
f. Totals might differ from sums due to rounding.

Radiation can cause a variety of adverse health effects in people. The following discussion is an overview of the method commonly used to estimate effects of radiation exposure; Appendix F contains more detailed information. At low doses, the most important adverse health effect for depicting the consequences of environmental and occupational radiation exposures (which are typically low doses) is the potential inducement of cancers that can lead to death in later years. This effect is referred to as *latent cancer fatalities* because the cancer can take years to develop and for death to occur, and might never actually be the cause of death.

The collective dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. This is referred to as a *population dose*. The total population dose received by the exposed population is measured in *person-rem*. For example, if 1,000 people each received a dose of 0.001 rem, the population dose would be 1.0 person-rem (1,000 persons multiplied by 0.001 rem equals 1.0 person-rem). The same population dose (1.0 person-rem) would result if 500 people each received a dose of 0.002 rem (500 persons multiplied by 0.002 rem equals 1 person-rem).

The factor used in this EIS to relate a dose to its potential effect is 0.0004 latent cancer fatality per person-rem for workers and 0.0005 latent cancer fatality per person-rem for individuals among the general population (DIRS 101856-NCRP 1993, p. 3). The latter factor is slightly higher because some individuals in the public, such as infants, might be more sensitive to radiation than workers. These risk factors have also been endorsed by the International Commission on Radiological Protection, Nuclear Regulatory Commission, and National Council on Radiation Protection and Measurements. The Environmental Protection Agency recently published an age-specific risk factor of 0.000575 latent cancer fatality per person-rem (DIRS 153733-EPA 2000, Table 7.3, p. 179), which is discussed in Appendix F. Both the Agency and DOE recognize that there are large uncertainties associated with these risk factors. As a consequence, DOE believes that the 15-percent difference in these risk factors (between 0.0005 and 0.000575) is well within other uncertainties and would provide little additional information to the decisionmaking process supported by this document. For these reasons, in its National Environmental Policy Act documents, DOE has continued to use risk factors recommended by the International Commission on Radiological Protection.

These concepts can be used to estimate the effects of exposing a population to radiation. For example, if 100,000 people were each exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities could occur as a result of 1 year of exposure (100,000 persons multiplied by 0.3 rem per year multiplied by 0.0005 latent cancer fatality per person-rem equals 15 latent cancer fatalities).

Calculations of the number of latent cancer fatalities associated with radiation exposure do not normally yield whole numbers and, especially in environmental applications, can yield numbers less than 1.0. For example, if 100,000 people were each exposed to a total dose of only 1 millirem (0.001 rem), the population dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05 (100,000 persons multiplied by 0.001 rem multiplied by 0.0005 latent cancer fatality per person-rem equals 0.05 latent cancer fatality).

The *average* number of deaths that would result if the same exposure situation were applied to many different groups of 100,000 people is 0.05. In most groups, nobody (zero people) would incur a latent cancer fatality from the 1-millirem dose each member would have received. In a small fraction of the groups, 1 latent fatal cancer would result; in exceptionally few groups, 2 or more latent fatal cancers would occur. The average number of deaths over all the groups would be 0.05 latent fatal cancer (just as the average of 0, 0, 0, and 1 is 0.25). The most likely outcome is no latent cancer fatalities in these different groups.

To aid in decisionmaking, DOE has applied these same concepts in estimating the effects of radiation exposure on a single individual. Consider the effects, for example, of exposure to background radiation over a lifetime. The probability of a latent cancer fatality corresponding to a single individual's exposure to 0.3 rem a year over a (presumed) 70-year lifetime is:

Probability of a latent cancer fatality = 1 person × 0.3 rem per year × 70 years
× 0.0005 latent cancer fatality per person-rem
= 0.011 probability of a latent cancer fatality.

Again, this should be interpreted in a statistical sense; that is, the estimated effect of background radiation exposure on the exposed individual would produce a 1.1-percent chance that the individual would incur a latent fatal cancer. For comparison purposes, statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer from all causes (DIRS 153066-Murphy 2000, p. 83).

3.1.8.2 Radiation Environment in the Yucca Mountain Region

Ambient radiation levels from cosmic and terrestrial sources at Yucca Mountain are higher than the U.S. average. The higher elevation at Yucca Mountain results in higher levels of cosmic radiation due to less shielding by the atmosphere. The U.S. average for cosmic, cosmogenic, and terrestrial radiation exposures is 56 millirem per year (Table 3-30). The exposures at the Yucca Mountain ridge and Yucca Mountain surface facilities are about 160 and 150 millirem per year, respectively. Moreover, there are higher amounts of naturally occurring radionuclides in the soil and parent rock of this region than in some other regions of the United States, which also results in higher radiation doses.

The surface environment, or soil, of Yucca Mountain contains the following naturally occurring radionuclides (DIRS 146183-CRWMS M&O 1996, all):

Radionuclide	Dry weight concentration (picocuries per gram)
Uranium-238	0.002 to 0.22
Radium-226	0.77 to 3.3
Thorium-232	0.17 to 0.92
Potassium-40	18 to 35

DOE measured external dose rates on the surface with thermoluminescent dosimeters at 64 to 127 millirem per year. This compares to an average annual dose from cosmic, cosmogenic, and terrestrial radiation in the Amargosa Valley of 96 millirem per year (Table 3-30).

With respect to the subsurface environment, the content of naturally occurring uranium and thorium in rock at Yucca Mountain has been measured at 2 to 6 and 15 to 35 milligrams per kilogram, respectively (DIRS 105946-Vaniman et al. 1996, Table 1-5; DIRS 155605-Bush, Bunker, and Spengler 1983, Table 1, pp. 4 to 7). The activity concentrations for uranium-238 are about 0.7 to 1.7 *picocurie* per gram, and for thorium-232 they are about 1.7 to 3.7 picocuries per gram. The activity concentrations of uranium and thorium decay products, including various isotopes of radium, should be in equilibrium in undisturbed rock and have the same activity concentration as the respective precursor radionuclide. The potassium content of the rock ranges from about 1 to 5 percent (DIRS 155605-Bush, Bunker, and Spengler 1983, Table 1, pp. 4 to 7). Because the natural abundance of radioactive potassium-40 is about 0.012 percent, the potassium-40 content of the rock ranges from about 1.4 to 5.9 milligrams per kilogram, an activity concentration of 10 to 41 picocuries per gram. Appendix F, Section F.1.1.6 discusses the range of background external radiation levels in the Exploratory Studies Facility. External exposure rates range from 0.014 to 0.038 millirem per hour and the median dose to a subsurface worker would be about 50 millirem per year.

The Yucca Mountain Project and the DOE Nevada Operations Office (in conjunction with the Environmental Protection Agency) conduct environmental surveillances around the Nevada Test Site. This monitoring has identified no radioactivity attributable to current operations at the Test Site. It did detect trace amounts of manmade radionuclides from worldwide nuclear testing in milk, game, and foods and in soil. Even though the monitoring has not detected ongoing releases to the environment related to the Test Site, DOE has made quantitative estimates of offsite doses from releases from past weapons testing activities at the Nevada Test Site (DIRS 155569-Townsend and Grossman 2000, pp. 7-1 to 7-4). DOE discusses estimates of radiation doses to the general population from past test site activities at the end of this section. Sources of ongoing releases at the Nevada Test Site include water containment ponds and contaminated soil resuspension. The estimated maximum annual radiation dose to a hypothetical individual in Springdale, Nevada [approximately 14 kilometers (9 miles) north of Beatty on U.S. 95], from airborne radioactivity is 0.12 millirem and 0.38 person-rem to the population within 80 kilometers (50 miles) of Nevada Test Site airborne emission sources. The maximum hypothetical-individual dose, which is about 1 percent of the 10-millirem-per-year dose limit that the Environmental Protection Agency established for a member of the public from emissions to the air from manmade sources (40 CFR Part 61), is conservative because data from offsite surveillance do not support doses of this magnitude.

Workers in the Exploratory Studies Facility can inhale naturally occurring radon-222 (a radioactive *noble* gas that is a decay product of naturally occurring uranium in rock) and its radioactive decay products. Radon concentration measurements during working hours, at a location representative of repository conditions, ranged from about 0.24 to 65 picocuries per liter (5th to 95th percentile), with a median concentration of about 13 to 17 picocuries per liter (DIRS 156114-Carl 2001, all). The median annual dose to Exploratory Studies Facility workers from inhalation of radon and decay products underground was estimated to be about 15 millirem, with an average of about 40 millirem and range from 0 to 180 millirem (5th to 95th percentile) (DIRS 156118-Gonzalez 2001, all). Appendix F, Section F.1.1.6, contains additional information on the estimated underground dose to *involved workers* from radon.

Workers in the Exploratory Studies Facility are also exposed to external gamma radiation from radon decay products and other naturally occurring radionuclides. Ambient radiation monitoring in this facility indicated a dose rate from background sources of radionuclides in the drift walls of about 0.014 to 0.038 millirem per hour, which would be about 50 millirem per year for a 2000-hour work year (see Appendix F, Section F.1.1.6).

Naturally occurring radon-222 and decay products are released from the Exploratory Studies Facility in the exhaust ventilation air. The estimated annual release of radon and decay products is about 80 curies. The estimated annual dose to an individual 20 kilometers (12 miles) south of the repository is less than 0.1 millirem. The estimated annual dose to the population within 80 kilometers (50 miles) is about 10 person-rem. These doses are small percentages of the dose from natural sources shown in Table 3-30. Appendix G contains additional information on the estimated releases of radon from the repository.

Effects from Past Nevada Test Site Weapons Testing. The history of the testing of nuclear weapons can be broadly divided into two eras, the era in which testing was predominantly performed above ground (1951 to 1961) and the era in which testing was performed predominantly underground (1961 to 1992). Since 1992, there has been a moratorium on nuclear testing. DOE described the activities at the Nevada Test Site in a previous NEPA document, the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all).

Radiation doses to the population surrounding the Nevada Test Site have been the subject of several reports since the inception of the nuclear weapons testing program. For example, the National Council on Radiation Protection and Measurements published estimates of effective dose equivalents in its Publication 93 (DIRS 101855-NCRP 1987, all), in which it reported an average dose commitment to each individual in the United States from all weapons testing of approximately 250 millirem received up through 2000 with very little received thereafter from deposition in the body.

A more recent report prepared by the National Cancer Institute (DIRS 152469-Institute of Medicine and National Research Council 1999, all) evaluated doses to the thyroid glands of individuals from iodine-131 but did not estimate doses from other radionuclides. That report calculated thyroid doses for each series of nuclear weapons tests that had occurred and concluded that approximately 98 percent of the dose to the population due to iodine-131 deposition in the thyroid gland was from the atmospheric weapons testing, with approximately 2 percent due to underground testing.

The calculated average dose to the thyroid gland of individuals in Nevada ranged from 0.5 *rad* to 5.0 rad (which is close to 0.5 rem to 5.0 rem) for residents who lived in the area during all the tests. The

National Cancer Institute further estimated an exposed population of 213,000 for iodine-131 exposure. The majority of that exposed population resided outside the region of influence evaluated in this EIS at the time of their exposure.

As discussed by the National Council on Radiation Protection and Measurements (DIRS 101855-NCRP 1987, all), because of the time that has elapsed since the occurrence of atmospheric nuclear weapons testing, much of the radioactivity in the environment with the potential to cause appreciable radiation dose has undergone decay. Therefore, individuals with the greatest potential for appreciable radiation doses from weapons testing would be those who were born before the 1960s, with less potential for those born later.

3.1.8.3 Health-Related Mineral Issues Identified During Site Characterization

Certain minerals known to present a potential risk to worker health are present in the volcanic rocks at Yucca Mountain (DIRS 101779-DOE 1998, Volume 1, pp. 2-24 and 2-25). The risks are generally related to potential exposures caused by inhalation of airborne particulates (dust). Some of the minerals represent a hazard commonly associated with underground construction, whereas others are rare and less well known.

Crystalline silica (silicon dioxide) comes in several forms—among them quartz, tridymite, and cristobalite. Inhaling silica dust causes a disease called *silicosis* that damages an area of the lungs called the air sac (alveoli) (DIRS 103243-EPA 1996, all). The presence of silica dust in the alveoli causes a defensive reaction that results in the formation of scar tissue in the lungs. This scar tissue can reduce overall lung capacity.

DOE typically performs evaluations of exposure to crystalline silica at Yucca Mountain for cristobalite that encompass potential impacts from exposure to other forms of crystalline silica. The repository host rock has a cristobalite content ranging from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). The American Conference of Governmental Industrial Hygienists has established Threshold Limit Values for various forms of crystalline silica (DIRS 103070-ACGIH 1999, p. 61). These limits are based on an 8-hour day and 40-hour week and, therefore, could be exceeded for a short period—as long as the average time spent by a worker is below the limit. The Threshold Limit Values for respirable cristobalite dust and quartz dust are 0.05 and 0.1 milligram per cubic meter, respectively. In addition, crystalline silica has been listed by the World Health Organization as a *carcinogen* (DIRS 100046-IARC 1997, p. 41).

Normal underground mechanical excavation produces dust when the rock is broken loose from the face. Dust is also generated when the broken rock is transferred to railcars or conveyors, or a storage pile. Dust can also be generated by wind erosion of excavated rock storage piles. Excavation activities during site characterization have caused exceedances of crystalline silica Threshold Limit Values at specific work locations. Workers at these locations were required to wear respirators. DOE will use the experience gained during Exploratory Studies Facility activities to design engineering controls to minimize future exposures.

Erionite is an uncommon zeolite mineral that the International Agency for Research on Cancer recognized as a human carcinogen in 1987; at Yucca Mountain, it occurs primarily in the basal vitrophyre of the Topopah Spring tuff and in isolated zones of the Tiva Canyon tuff (see Section 3.1.3). Even at low concentrations erionite is believed to be a potent carcinogen capable of causing mesothelioma, a form of lung cancer. As a result of its apparent carcinogenicity, erionite could pose a risk if encountered in quantity during underground construction, even with standard modern construction practices. Because erionite appears to be absent or rare at the proposed repository depth and location, most repository operations should not be affected. However, repository workers would take precautions (for example, dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (DIRS 100046-IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total *recordable* incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) *lost workday cases* (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Site characterization activities at Yucca Mountain have had no involved worker fatalities. DOE has compiled statistics for the other types of health and safety impacts in accordance with the regulations of the Occupational Safety and Health Administration (29 CFR Part 1904) (see Appendix F, Section F.2). These statistics cover the 30-month period from the fourth quarter of 1994 through the first quarter of 1997. DOE selected this period because there was high onsite work activity in which the tunnel-boring machine was in operation in the Exploratory Studies Facility. DOE expects this condition to be characteristic of the types of activities that would occur during the construction of the surface facilities and the development of the emplacement drifts. Table 3-31 lists the industrial health and safety loss statistics for industry, general construction, general mining, and the Yucca Mountain site.

Table 3-31. Comparison of health and safety statistics for mining activities from the Bureau of Labor Statistics to those for Yucca Mountain during excavation of the Exploratory Studies Facility.[a]

Statistic	Total industry[b]	General construction[b]	General mining[b]	Yucca Mountain experience for involved workers[c]
Total recordable cases rate	7.1	9.5	5.9	6.8
Lost workday cases rate	3.3	4.4	3.7	4.8
Fatality rate	Not available	Not available	Not available	0.0[d]

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: DIRS 148091-BLS (1998, all).
c. Source: Appendix F, Section F.2.
d. There have been no fatalities on the Yucca Mountain Project. However, the fatality rate obtained from the entire DOE CAIRS database for industrial activities is 0.0029 per 100 full-time equivalent work years.

3.1.9 NOISE AND VIBRATION

The region of influence for noise includes existing residences in the Yucca Mountain region and at the approximate boundary of the analyzed land withdrawal area. Noise comes from either natural or dust suppression, air filters, personal protective gear) during construction when penetrating horizons in which erionite could occur, such as in the basal vitrophyre of the Topopah Spring tuff.

A number of other minerals present at Yucca Mountain might have associated health risks if prolonged exposures occur; however, there is no evidence suggesting a link to cancer. Therefore, the International Agency for Research on Cancer has ranked these substances not classifiable (DIRS 100046-IARC 1997, all). Some of the minerals identified and considered in establishing health and safety practices for potential repository operations include the zeolite group minerals mordenite (which is fibrous and similar in some respects to erionite), clinoptilolite, heulandite, and phillipsite. Because there is no known risk associated with the other zeolite minerals, and because they occur primarily in nonwelded units below the repository horizon, they probably do not represent a large risk. The measures implemented to mitigate risk from silica (for example, dust suppression, air filters, personal protective gear) should also protect workers from exposure to other minerals.

3.1.8.4 Industrial Health and Safety Impacts During Construction of the Exploratory Studies Facility

During Yucca Mountain site characterization activities, health and safety impacts to workers have resulted from common industrial hazards (such as tripping and falling). The categories of worker impacts include total *recordable* incidents, lost workdays, and fatalities. Recordable incidents or cases are occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) *lost workday cases* (nonfatal), and (3) incidents that result in the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

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Fatality rate	Not available	Not available	Not available	0.0[d]

a. Statistics based on 100 full-time equivalent work years or 200,000 worker hours.
b. Source: DIRS 148091-BLS (1998, all).
c. Source: Appendix F, Section F.2.
d. There have been no fatalities on the Yucca Mountain Project. However, the fatality rate obtained from the entire DOE CAIRS database for industrial activities is 0.0029 per 100 full-time equivalent work years.

3.1.9 NOISE AND VIBRATION

The region of influence for noise includes existing residences in the Yucca Mountain region and at the approximate boundary of the analyzed land withdrawal area. Noise comes from either natural or manmade sources. DOE has evaluated existing noise conditions in the Yucca Mountain region and has compiled the detected ranges of noise levels at different locations under differing conditions.

3.1.9.1 Noise Sources and Levels

Yucca Mountain is in a quiet desert environment where natural phenomena such as wind, rain, and wildlife account for most background noise. The acoustic environment is typical of other desert environments where average day-night sound-level values range from 22 decibels on calm days to 38 decibels on windy days (DIRS 102224-Brattstrom and Bondello 1983, p. 170).

Manmade noise occurs periodically in the area as vehicles travel to and from Yucca Mountain, from site characterization activities at the operations areas, and from occasional low-flying military jets. Sound-level measurements recorded in May 1997 at areas adjacent to and at the Yucca Mountain operations areas were consistent with noise levels associated with industrial operations [sound levels from 44 to 72 decibels (A-weighted)] (DIRS 101531-Brown-Buntin 1997, pp. 4-6). Table 3-32 lists estimated sound-level values for Yucca Mountain, nearby communities and cities, and other environments.

Table 3-32. Estimated sound levels in southern Nevada environments.[a]

Environment	Sound level[b] (decibels)
Calm day at Yucca Mountain	22
Windy day at Yucca Mountain	38
Rural communities (Panaca, Hadley, Rachel, Crystal Springs, Ash Springs, Cactus Springs, Alamo, Jean, Goodsprings, Sandy)	40 - 47
Small towns or rural communities along busy highways (Beatty, Indian Springs, Pahrump, Amargosa Valley, Caliente, Tonopah, Goldfield, Mercury) and at the intersection of proposed transportation routes to Yucca Mountain	45 - 55
Suburban parts of Las Vegas	52 - 60
Urban parts of Las Vegas	56 - 66
Dense urban parts of Las Vegas with heavy traffic	64 - 74
Under flight path at McCarran International Airport (0.8 to 1.6 kilometers[c] from runway)	78 - 88

a. Source: Modified from DIRS 101821-EPA (1974, p. 14); DIRS 102224-Brattstrom and Bondello (1983, p. 170).
b. Day-night average sound level.
c. About 0.5 to 1 mile.

3.1.9.2 Regulatory Standards

With the exception of prohibiting nuisance noise, neither the State of Nevada nor local governments have established numerical noise standards. Nevertheless, many Federal agencies use average day-night sound levels as guidelines for land-use compatibility and to assess the impacts of noise on people. Many agencies, including the Environmental Protection Agency, recognize an average day-night sound level of 55 decibels (A-weighted) as an outdoor goal for protecting public health and welfare in residential areas (DIRS 101821-EPA 1974, p. 3). This noise level, which has been established by scientific consensus, is not a regulatory criterion in Nevada, and could protect against activity interference and annoyance. While Nevada does not have a noise code, daytime and nighttime noise standards adopted by Washington State (WAC-173-60 and 70) for residential and commercial areas can serve as benchmarks for evaluating potential impacts based on land use. These benchmarks are 60 decibels for residential use (nighttime reduction to 50 decibels), 65 decibels for light commercial, and 70 decibels for industrial zones. As required, DOE monitors noise levels in worker areas, and a hearing protection program has been in place during site characterization. Hearing protection is used as a supplement to engineering controls, which are the primary method of noise suppression.

Sound levels that cause annoyance in people vary greatly by individual and background conditions. However, the threshold for hearing hazard, which depends on the frequency of the sound, ranges from around 65 decibels at a frequency of 4,000 hertz to about 88 decibels at frequencies of 125 and 8,000 hertz (DIRS 155778-Melnick 1998, Vol. 12, p. 18). These threshold levels assume continuous exposure for periods of hours. High risk for hearing loss occurs at 120 decibels and can result from short-term exposure of seconds to minutes. Ground transportation activities such as those associated with the Proposed Action (either rail or heavy-haul trucks) would not propagate noise levels of this magnitude to the environment.

3.1.9.3 Vibration

Ground vibration is an element of environmental assessment. Many natural phenomena (wave action on beaches, strong winds, earthquakes, etc.) as well as human activities (construction, transportation, military activities, etc.) can contribute to ground vibration. As a consequence, there is a component of background vibration that exists, generally higher in large cities than in rural communities, and lower in areas more distant from human activities. This vibration component can be altered by a change in site activities.

There are two measurements for evaluating ground vibration: peak particle velocity and root-mean-square velocity (DIRS 155547-HMMH 1995, p. 7-3). *Peak particle velocity* is the maximum instantaneous positive or negative peak of the vibration signal, measured as a distance per time (such as millimeters or inches per second). This measurement has been used historically to evaluate "shock"-wave type vibrations from actions like blasting, pile driving, and mining activities, and their relationship to building damage. The root-mean-square level is an average or smoothed vibration amplitude, commonly measured over 1-second intervals. It is expressed on a log scale in decibels (VdB) referenced to 0.000001 (10^{-6}) inch per second and is not to be confused with noise decibels. It is more suitable for addressing human annoyance and characterizing background vibration conditions because it better represents the response time of humans to ground vibration signals.

A typical background level of ground vibration is 52 VdB, and the human threshold for the perception of ground vibration is 65 VdB (DIRS 148155-Hanson, Saurenman, and Towers 1998, p. 46.17). There are three ground vibration impacts of general concern: human annoyance, damage to buildings, and interference to vibration-sensitive activities. Three categories of buildings and associated human activities have been established for the assessment of annoyance or interference impacts from ground vibration (DIRS 155547-HMMH 1995, pp. 8-2 to 8-3). Table 3-33 lists these categories along with associated benchmark vibration levels at which adverse impacts might be likely. An important element of the criteria for human disturbance is the frequency of distinct ground vibration events; the more events, the higher the likelihood of annoyance. Most environmental evaluations have focused on mass transit, where there is a high frequency of events.

Vibration criteria for structural damage in fragile or extremely fragile buildings have separate structural criteria based on peak particle velocity and an approximation of VdB that have been segregated into impulse and rail impacts. Table 3-33 lists these criteria. Building damage from ground vibration, which is rare, is associated with vibration levels that are unpleasant or disturbing long before there is any possibility of damage to the building.

Background levels of ground vibration at the Yucca Mountain site are low. Other than site characterization-related activities, there is basically a lack of the classical, manmade sources of ground vibration impacts; that is, impacts from pile driving, heavy earth-moving equipment (particularly equipment with metal tracks), and blasting.

NOISE MEASUREMENT

What are *sound* and *noise*?

When an object vibrates it possesses energy, some of which transfers to the air, causing the air molecules to vibrate. The disturbance in the air travels to the eardrum, causing it to vibrate at the same frequency. The ear and brain translate the vibration of the eardrum to what we call *sound*. *Noise* is simply unwanted sound.

How is sound measured?

The human ear responds to sound pressures over an extremely wide range of values. The range of sounds people normally experience extends from low to high pressures by a factor of 1 million. Accordingly, scientists have devised a special scale to measure sound. The term decibel (abbreviated dB), borrowed from electrical engineering, is the unit commonly used.

Another common sound measurement is the A-weighted sound level, denoted as dBA. The A-weighting accounts for the fact that the human ear responds more effectively to some pitches than others. Higher pitches receive less weighting than lower ones. Most of the sound levels provided in this EIS are A-weighted; however, some are in decibels due to lack of information on the frequency spectrum of the sound. The scale to the right provides common references to sound on the A-weighted sound-level scale.

Source: Modified from DIRS 103233-DOE (1999, p. 3-39)

TYPICAL A-WEIGHTED SOUND LEVELS

	DECIBELS	
	140	
50-horsepower siren (33 meters)[a]		
	130	
Jet takeoff (66 meters)		
	120	Diesel motors
Riveting machine[b]		
	110	
Cut-off saw Pneumatic peen hammer[b]		
	100	Outdoor public address system loudspeakers
Rock drill (16 meters) Textile weaving plant[b]		
Subway train (6.6 meters)	90	
Dump truck (16 meters) Pneumatic drill (16 meters)		Ventilation fans
	80	
Freight train (33 meters) Vacuum cleaner (3.3 meters)		Inside sports car (24 meters per second)[c]
Speech (0.33 meters)	70	
Passenger auto (16 meters)		Near freeway (auto traffic)
	60	Large store
Large transformer (66 meters)		Accounting office
	50	Private business office Light traffic (33 meters) Average residence
	40	
Soft whisper (13 centimeters)[d]		
	30	Studio (speech)
	20	Quiet
	10	
Threshold of hearing (youths)	0	

a. To convert meters to feet, multiply by 3.2808.
b. Operator's position.
c. 24 meters per second = about 50 miles per hour.
d. 13 centimeters = about 5 inches.

3.1.10 AESTHETICS

Visual resources, with nighttime darkness as a component, include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The physical features representing the region of influence for aesthetics are those found within the approximate boundary of the analyzed land withdrawal area. Sections 3.1.3 and 3.1.5 describe the geologic and biological settings, respectively, at Yucca Mountain.

The region surrounding Yucca Mountain consists of unpopulated to sparsely populated desert and rural lands. Because much of Yucca Mountain is on the Nevada Test Site and Nellis Air Force Range with restricted public access, public visibility is limited to portions of U.S. Highway 95 near Amargosa Valley.

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Table 3-33. Benchmark ground vibration criteria for buildings and human annoyance.[a]

Category	Frequent events (>70/day) VdB[b]	Infrequent events (<70/day) PPV (in/sec)[c]	Infrequent events (<70/day) VdB	Impact of concern
Annoyance or interference				
1. High sensitive buildings[d]	65	NA[e]	65	Sensitive equipment
2. Residential[f]	72	NA	80	Human disturbance
3. Institutional[g]	75	NA	83	Human disturbance
Structural damage				
Fragile buildings	NA	0.20	~100 (Impulse) 92 (Rail)	Structural damage
Extremely fragile buildings	NA	0.12	~95 (Impulse 88 (Rail)	Structural damage

a. Source: DIRS 155547-HMHH (1995, p. 8-3).
b. Root-mean-square velocity expressed in decibels - VdB - referenced to 10^{-6} inch per second.
c. Peak particle velocity in inches per second; to convert to millimeters per second, multiply by 25.4.
d. Buildings with vibration-sensitive equipment (for example, at research institutions and medical facilities).
e. NA = not applicable.
f. Homes or buildings where people sleep.
g. Schools, churches, and office buildings.

The Bureau of Land Management uses four visual resource classes in the management of public lands (DIRS 101505-BLM 1986, all). Classes I and II are the most valued, Class III is moderately valued, and Class IV is of least value. Visual resources fall into one of these management classes based on a combination of three factors: (1) scenic quality, (2) visual sensitivity, and (3) distance from travel routes or observation points (DIRS 101505-BLM 1986, all). There are three scenic quality classes in the Bureau of Land Management Visual Resource Management system. Class A includes areas that combine the most outstanding characteristics of each physical feature category. Class B includes areas in which there is a combination of some outstanding and some fairly common characteristics. Class C includes areas in which the characteristics are fairly common to the region. A visual sensitivity rating for an area is based on the number and types of users, special areas (natural areas, wilderness areas), public interest in the area, and adjacent land uses. Though a scenic quality rating (A, B, or C) is used in conjunction with visual sensitivity and distance zones (foreground, middleground, background, and seldom seen) to produce Visual Resource Management Classes, the scenic quality rating is often used independently to emphasize a visual resource within a management class area. For example, a Wilderness Study Area might have a Class A scenic rating and be in a Class II or III management area.

The Bureau of Land Management has not assigned a Visual Resource Management class to Yucca Mountain because the Nevada Test Site is not under the Bureau's jurisdiction. However, using the Bureau's method of determining scenic quality, DOE has evaluated the visual resources of the Yucca Mountain region from two observation points—one at Amargosa Valley on U.S. 95 and the other on the Nevada Test Site at a location that provides a clear view of the proposed repository site (DIRS 105002-CRWMS M&O 1999, all).

The visual assessment at both these locations concluded that the scenic quality classification of Yucca Mountain is C.

Nighttime darkness in the Yucca Mountain region is a valued component of the solitude experience sought by many individuals, and greatly enhances astronomy and stargazing activities. It is also felt to be one of the important scenic resources of the Death Valley National Park. Existing or potential sources of nighttime light in this area include the Towns of Beatty and Amargosa Valley that lie between Death Valley National Park and the Yucca Mountain site; the community of Pahrump slightly east of the Park; and Las Vegas farther to the east. Las Vegas is the largest source of nighttime light in the extended region; the glow of its lights is evident in the night sky at much farther distances than other city features.

BUREAU OF LAND MANAGEMENT VISUAL RESOURCE MANAGEMENT CLASS OBJECTIVES (used in the management of public lands)

Class I	The objective of this class is to preserve the existing character of the landscape. This class provides for natural ecological changes; however, it does not preclude very limited management activity. The level of change to the characteristic landscape should be very low and must not attract attention.
Class II	The objective of this class is to retain the existing character of the landscape. The level of change to the characteristic landscape should be low. Management activities may be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture found in the predominant natural features of the characteristic landscape.
Class III	The objective of this class is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape.
Class IV	The objective of this class is to provide for management activities that require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high. These management activities may dominate the view and be the major focus of viewer attention. However, every attempt should be made to minimize the impact of these activities through careful location, minimal disturbance, and repeating the basic elements.

Current lighting at the repository site is similar to or less than lighting at other work areas on the Nevada Test Site and represents a minor contribution to the area's sources of nighttime lighting.

3.1.11 UTILITIES, ENERGY, AND SITE SERVICES

DOE research into the current consumer demand for utilities and energy in the Yucca Mountain region has yielded information on water and power sources, use, and supply systems. The research included water treatment capabilities. The region of influence for potential impacts to utility and energy supplies consists of those public and private resources on which DOE would draw to support the Proposed Action, and which are in Clark, Lincoln, and Nye Counties in Nevada. Sections 3.1.11.1 and 3.1.11.2 contain information on current water and energy suppliers and consumer use. Unless otherwise noted, the *Yucca Mountain Site Characterization Project Environmental Baseline File for Utilities, Energy, and Site Services* (DIRS 104988-CRWMS M&O 1999, all) is the basis of the information in this section.

3.1.11.1 Utilities

Water and sewer utilities in the region could be affected by the Proposed Action as a result of project-related increases in population and the associated increases in water demand and sewage production. DOE anticipates that the predominant project-related increase in population would occur in Clark County, with a smaller increase in Nye County (see Section 3.1.7).

Water. The Southern Nevada Water Authority supplies water to five communities in Clark County: Boulder City, Henderson, Las Vegas (including parts of unincorporated Clark County), Nellis Air Force

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Base, and North Las Vegas. Eighty-five percent of the water supplied to the Las Vegas Valley comes from the Colorado River through Lake Mead; the remaining 15 percent comes from groundwater (Las Vegas Valley Hydrographic Area; DIRS 101923-SNWA 1997, p. 2). To meet growing water demands, the Water Authority is upgrading current facilities and installing new facilities, such as a second raw water intake at Lake Mead, a second water treatment facility, and additional pipelines and pumping stations.

In southern Nye County, where the repository would be, groundwater is the only source of water. In August 1996, a water supply and demand evaluation for southern Nye County, including Beatty, Amargosa Desert, and Pahrump, was performed (DIRS 101542-Buqo 1996, all). The evaluation indicated the Beatty (Oasis Valley Hydrographic Area) water utility would have difficulty meeting future water demands due not to a high growth rate but to falling well yields and poor water quality in some wells. It further predicted that existing pumping capacity would not be adequate to meet projected peak demands between 1997 and 2000, and one or more additional wells would be needed. Since the 1996 evaluation, Beatty has gained the use of another well (formerly used by the Bullfrog Mine), which has provided a capacity sufficient to meet water demand now and for the immediate future, even while ending the use of two wells with high fluoride (DIRS 156759-Davis 2001, all). In Amargosa Desert (Amargosa Desert Hydrographic Area), the current committed amount of groundwater appropriations (permits and certificates) is larger than the lower estimate of perennial yield for the applicable groundwater. However, historic pumping amounts have never been higher than the estimates of yield. In Pahrump (Pahrump Valley Hydrographic Area), the total groundwater pumped from the basin in 1995 was almost 30 million cubic meters (24,000 acre-feet). This is about 25 percent higher than the upper end of estimates of the basin’s perennial yield, which range from 15 million cubic meters [12,000 acre-feet (DIRS 103406-NDWP 1992, Region 10)] to 23 million cubic meters [19,000 acre-feet (DIRS 101542-Buqo 1996, p. 17)]. Much of Pahrump’s water consumption results from about 7,000 domestic water supply wells. Drilling continues at a rate of about 700 wells a year (DIRS 103099-Buqo 1999, p. 36) . Alternatives to address long-term water supply issues in Pahrump Valley include optimizing the locations of new wells, reducing per capita consumption, developing the carbonate aquifer, and importing water from other groundwater basins. Overall groundwater withdrawals in Nye County totaled about 93 million cubic meters (75,000 acre-feet) in 1995. The predominant use of this water was agriculture, accounting for 80 percent of the total; domestic use was responsible for only 7 percent of the total withdrawal (DIRS 104888-LeStrange 1997, Table 1).

Sewer. Wastewater treatment needs in the Las Vegas Valley are supported by three major wastewater treatment facilities: one operated by the City of Las Vegas (which also serves the City of North Las Vegas); one operated by the City of Henderson; and one operated by the Clark County Sanitation District. The County Sanitation District includes all the unincorporated areas in Clark County, and it provides services to several outlying communities including Blue Diamond, Laughlin, Overton, and Searchlight (DIRS 148106-Clark County Sanitation District 1999, all). However, its primary service area is the portion of the Las Vegas Valley south and east of the City of Las Vegas and extending to Henderson. There might be other small wastewater treatment units serving parts of Clark County outside the populous area of the Las Vegas Valley, but septic tank and drainage field systems provide the primary means of wastewater treatment in these outlying areas, particularly for private residences.

Southern Nye County does not have a metropolitan area or a sanitation district comparable to Clark County. Most communities in this area rely primarily on individual dwelling or small communal wastewater treatment systems, with the exception of Beatty, which has municipal sewer service. For example, Pahrump has no community-wide wastewater treatment system. Several wastewater treatment units serve parts of the town, such as the dairy and the jail, but most households have septic tank and drainage field systems. This is likely to be typical of the small communities in southern Nye County.

3.1.11.2 Energy

Electric Power. Three different power distributors—Nevada Power Company, Valley Electric Association, Inc., and Lincoln County Power District No. 1—supply electric power in the region of influence.

Nevada Power Company supplies electricity to southern Nevada in a corridor from southern Clark County, including Las Vegas, North Las Vegas, Henderson, and Laughlin, to the Nevada Test Site in Nye County. In 2000, the power sources were about 50 percent company-generated and about 50 percent purchased power. In 2000, Nevada Power Company sold 17.9 million megawatt-hours to its 620,000 customers, and the peak load was the highest ever at about 4,300 megawatts. Nevada Power Company has an annual customer growth rate of about 6 percent. To keep pace with demands for electricity, each year Nevada Power must build more substations and transmission and distribution facilities; in 2001 to 2003, it plans to invest about $320 million in such equipment (DIRS 155864-NPC 2000, all). Recent energy concerns have caused the forecasting of supply and demand to be much more uncertain than in the past, as reflected in recent planning documents released by Nevada Power Company. Nevada Power Company merged with Sierra Pacific Resources in July 1999 (DIRS 153929-NPC 1999, all). Sierra Pacific Resources is the holding company for the Sierra Pacific Power Company, which provides electric power to much of northern Nevada and the Lake Tahoe area.

The Valley Electric Association is a nonprofit cooperative that distributes power to southern Nye County, including Pahrump Valley, Amargosa Valley, Beatty, and the Nevada Test Site. The Western Area Power Administration allocates Valley Electric a portion of the lower cost hydroelectric power from the Colorado River dams. The private power market supplies the supplemental power necessary to meet the needs of the members. Since 1995, the amount of power available in the marketplace has been abundant. The amount of energy that Valley Electric sells annually to its members almost tripled in the 11 years from 1985 through 1995. In 1995, Valley Electric sold about 300 million kilowatt-hours to its 8,600 members (DIRS 101846-McCauley 1997, pp. 54 and 55). To meet the power demands of its members, Valley Electric has built a new 230-kilovolt transmission line from Las Vegas to Pahrump and plans to install three new substations in Pahrump.

At present, two commercial utility companies own transmission lines that supply electricity to the Nevada Test Site (Figure 3-26). The electric power for the Yucca Mountain Project in Area 25 comes through the Nevada Test Site power grid. The Test Site buys power at 138 kilovolts at the Mercury Switch Station and at the Jackass Flats Substation. The 138-kilovolt system at the Test Site has nine substations, one switching center, and one tap station, which are connected by approximately 210 kilometers (130 miles) of transmission line. A 138-kilovolt line owned by Nevada Power Company connects the Mercury Switch Station to the Jackass Flats substation, which reduces the power and transmits it to the Field Operations Center and nearby buildings in Area 25 that support the Yucca Mountain Project. A Valley Electric Association 138-kilovolt line also provides power to the Jackass Flats Substation. From the Jackass Flats substation, a 138-kilovolt line feeds the Canyon Substation in Area 25, which provides power to the Exploratory Studies Facility. The Canyon Substation reduces the voltage from 138 to 69 kilovolts, with a capacity of 10 megawatts, and transmits it to the Yucca Mountain substation at the Exploratory Studies Facility.

The capacity of the Nevada Test Site grid is 72 megawatts. Since 1990, the peak load was about 37 megawatts and occurred in January 1992 (DIRS 104955-LeStrange 1997, p. 1).

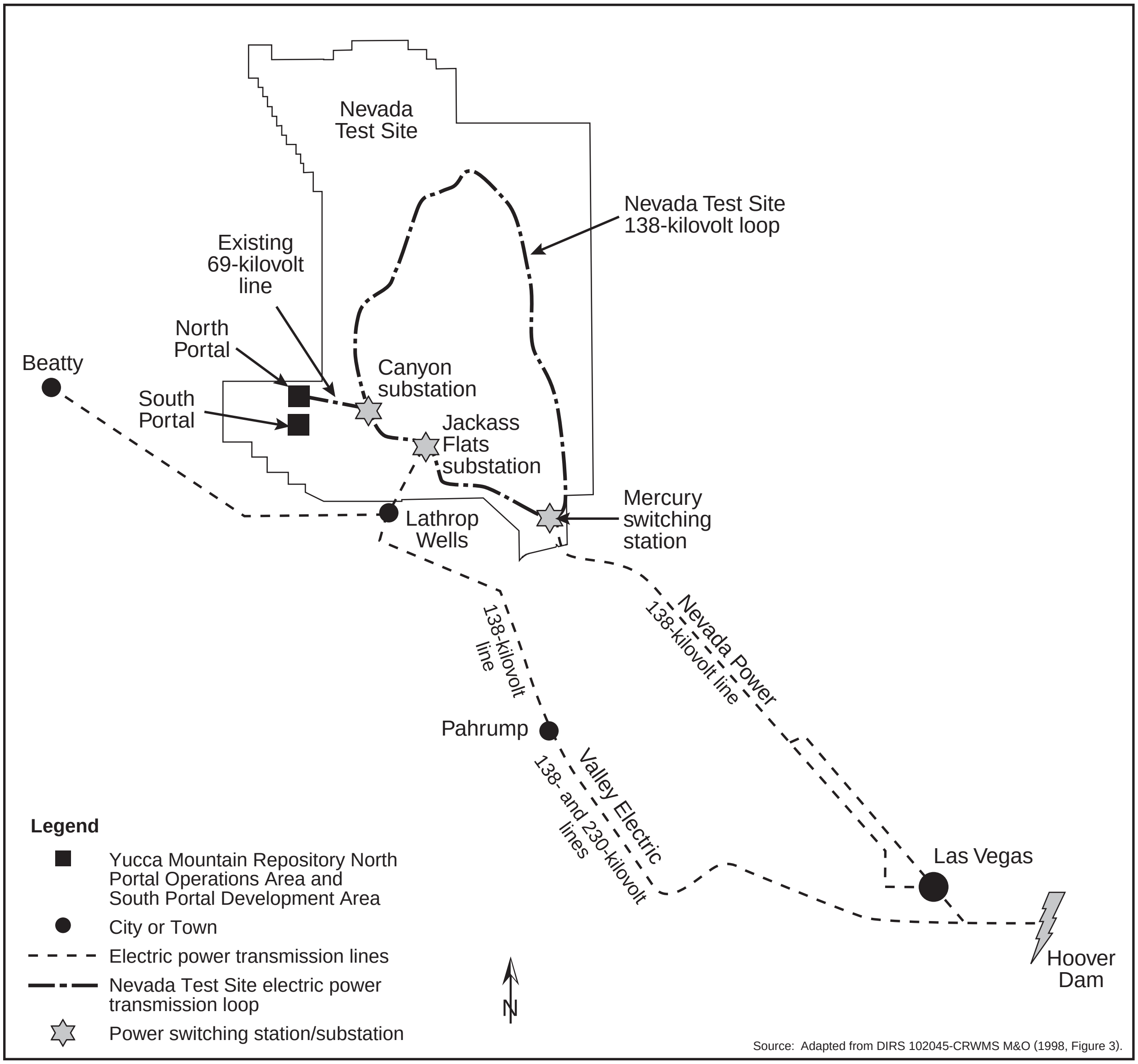

Figure 3-26. Existing Nevada Test Site electric power supply.

Table 3-34 lists the combined historic and projected electricity use for the Exploratory Studies Facility and the Field Operations Center for 1995 through 2000. The Exploratory Studies Facility consumed about 70 percent of the listed amounts (DIRS 104955-LeStrange 1997, all). Annual power use and peak demand at the Exploratory Studies Facility would probably decline and stabilize at a lower level than the 1997 use rates because site activity would decline until repository construction began in 2005. Historically, from 1995 through 1997 Exploratory Studies Facility use has accounted for about 15 percent to 20 percent of the electric power used by all of the Nevada Test Site (DIRS 104988-CRWMS M&O 1999, Table 2, p. 6).

Fossil Fuel. The fossil fuels that DOE has used at the Exploratory Studies Facility are heating oil, propane, diesel, gasoline, and kerosene. Natural gas, coal, and jet fuel have not been used. In 1996, site activities consumed about 1.02 million liters (270,000 gallons) of heating oil and diesel fuel and about 65,000 liters (17,000 gallons) of propane; in 1997, they consumed slightly less than 1 million liters (264,000 gallons) of heating oil and diesel fuels. The amounts of gasoline and kerosene used at the

Table 3-34. Electric power use for the Exploratory Studies Facility and Field Operations Center.[a,b]

	Power use	
Fiscal Year	Consumption (megawatt-hours)	Peak (megawatts)
1995	9,800	3.5
1996	19,000	4.9
1997	23,000	5.3
1998[c]	21,000	4.2
1999[c]	17,000	4.2
2000[c]	8,700	4.2

a. Source: DIRS 104988-CRWMS M&O (1999, Table 2, p. 6)
b. Before 1995, Yucca Mountain Project power was not metered separately.
c. Estimated.

Exploratory Studies Facility were very small in those years. Fossil-fuel supplies are delivered to the Nevada Test Site and the Exploratory Studies Facility by truck from readily available supplies in southern Nevada.

3.1.11.3 Site Services

DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DIRS 102618-YMP 1998, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff’s Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the “Flight for Life” and “Air Life” programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

3.1.12 WASTE AND HAZARDOUS MATERIALS

The region of influence for waste and hazardous materials consists of on- and offsite areas, including landfills and radioactive waste processing and disposal sites, in which DOE would dispose of waste generated under the Proposed Action. This region of influence can be described, to a large extent, through considering the manner in which waste has been managed during the current Yucca Mountain activities.

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (DIRS 152012-McCann 2000, pp. 1 to 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of *sanitary waste*. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and a 100-year estimated life (DIRS 101803-DOE 1995, p. 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill

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DOE has established an existing support infrastructure to provide emergency services to the Exploratory Studies Facility. The Yucca Mountain Project *Emergency Management Plan* (DIRS 102618-YMP 1998, all) describes emergency planning, preparedness, and response. The project cooperates with the Nevada Test Site in such areas as training and emergency drills and exercises to provide full emergency preparedness capability to the site. In addition, the project trains and maintains an underground rescue team. The Nevada Test Site security program is responsible for project security, with enforcement provided by a contractor following direction from DOE. The Nye County Sheriff's Department provides law enforcement and officers for Yucca Mountain site patrol. Nevada Test Site personnel and equipment support fire protection and medical services. Medical services are provided through the Nevada Test Site by two paramedics and an ambulance stationed in Area 25 with backup from other Test Site locations. The Yucca Mountain staff uses a medical clinic with outpatient capability at Mercury. Urgent medical transport is provided by the "Flight for Life" and "Air Life" programs from Las Vegas. Nellis Air Force Base and Nye County also provide emergency support.

3.1.12 WASTE AND HAZARDOUS MATERIALS

The region of influence for waste and hazardous materials consists of on- and offsite areas, including landfills and radioactive waste processing and disposal sites, in which DOE would dispose of waste generated under the Proposed Action. This region of influence can be described, to a large extent, through considering the manner in which waste has been managed during the current Yucca Mountain activities.

The Yucca Mountain Site Characterization Project developed its waste management systems to handle the waste and recyclable material generated by its activities. This material includes nonhazardous solid waste; construction debris; hazardous waste; recyclables such as lead-acid batteries, used oil, metals, paper, and cardboard (DIRS 152012-McCann 2000, pp. 1 to 6); sanitary sewage; and wastewater. It does not include low-level radioactive or mixed wastes. DOE uses landfills to dispose of solid waste and construction debris; accumulates and consolidates hazardous waste, then transports it off the site for treatment and disposal; treats and reuses wastewater; and treats and disposes of *sanitary waste*. In most categories of waste, especially solid waste, some types of material can be recycled or reused. DOE has processes in place to ensure that it collects the material and recycles it as appropriate.

3.1.12.1 Solid Waste

DOE disposes of Yucca Mountain Site Characterization Project solid waste and construction debris in landfills in Areas 23 and 9, respectively, on the Nevada Test Site. The Area 23 landfill has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and a 100-year estimated life (DIRS 101803-DOE 1995, p. 9). The Area 9 landfill, which is in Crater U-10C, is an open circular pit with steep, almost vertical sides formed as a result of an underground nuclear test. The Area 9 landfill has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37) and an estimated 70-year operational life (DIRS 101803-DOE 1995, p. 8). The environmental impact statement for the Nevada Test Site describes these landfills (DIRS 101811-DOE 1996, p. 4-37). DOE disposes of Yucca Mountain Site Characterization Project oil-contaminated debris from maintenance activities at the industrial landfill at Apex, Nevada, using an environmental company for transport and disposal. The Apex facility is a multilined landfill with on- and offsite monitoring in compliance with State of Nevada requirements (DIRS 152012-McCann 2000, p. 3).

DOE recycles as many materials as feasible from its site characterization activities. The *Waste Minimization and Pollution Prevention Awareness Plan, Approved* (DIRS 103203-YMP 1997, all) governs recycling and other waste minimization activities. At present, a Nevada Test Site contractor collects paper, cardboard, aluminum cans, and scrap metal and recycles it. For such recyclables as oils, solvents, coolants, lead-acid batteries, and oil-contaminated soils, the Yucca Mountain Site Characterization Project contracts directly with recycling services (DIRS 152012-McCann 2000, pp. 1 to 5).

Solid waste generated by the construction and operation of transportation facilities could be disposed of in offsite landfills. At present, there are 24 operating municipal solid waste landfills in Nevada (DIRS 155563-NDEP 2001, all) with a combined capacity to accept 11,000 metric tons (12,000 tons) of waste per day. In 2000, about 3.5 million metric tons (3.9 million tons) of sanitary solid waste was disposed of in Nevada (DIRS 155565-NDEP 2001, Section 2.1). Eleven Nevada landfills accept industrial and special waste (DIRS 155563-NDEP 2001, all), which includes construction debris and other solid waste such as tires that have specific management requirements for permitted landfill disposal. The State's largest regional landfill accepts municipal and industrial waste and has a capacity of 6,300 metric tons (6,900 tons) per day (DIRS 155563-NDEP 2001, all). In 2000, about 750,000 metric tons (823,000 tons) of construction debris and about 83,000 metric tons (91,000 tons) of other wastes were disposed of in the State (DIRS 155565-NDEP 2001, Section 2.1).

3.1.12.2 Hazardous Waste

The Yucca Mountain Site Characterization Project is a small-quantity [less than 1,000 kilograms (2,200 pounds) a month] generator of hazardous waste. DOE accumulates hazardous wastes near their generation sources, consolidates them at a central location at the Yucca Mountain site, and ships them off the site for treatment and disposal. The hazardous waste accumulation areas are managed in accordance with Federal and State regulations. The waste is treated and disposed of off the site at a permitted treatment, storage, and disposal facility (DIRS 152012-McCann 2000, p. 6).

3.1.12.3 Wastewater

DOE uses a septic system to treat and dispose of sanitary sewage at the Yucca Mountain site (DIRS 102303-CRWMS M&O 1998, p. 15). The system design can handle a daily flow of about 76,000 liters (20,000 gallons) (DIRS 102599-CRWMS M&O 1998, p. 64).

At present, wastewater from tunneling operations and water from secondary containment (following rains) is processed through an oil-water separator, and the treated water is used for dust suppression in accordance with a State of Nevada permit (DIRS 152012-McCann 2000, p. 4). The oil is recycled with the other used oil generated by the project.

3.1.12.4 Existing Low-Level Radioactive Waste Disposal Capacity

The Nevada Test Site accepts low-level radioactive waste for disposal from approved generator sites. It has an estimated disposal capacity of 3.7 million cubic meters (130 million cubic feet). DOE estimates that a total of approximately 1.1 million cubic meters (39 million cubic feet) of low-level radioactive waste will be disposed of at the Test Site through 2070 (DIRS 155856-DOE 2000, Table 4-1, p. 4-2), not including repository-generated waste.

Commercial spent nuclear fuel generators and contractor-operated transportation facilities such as an intermodal transfer station would dispose of low-level radioactive waste in commercial facilities. Commercial disposal capacity for low-level radioactive wastes is available at three licensed facilities (DIRS 152583-NRC 2000, U.S. Low-Level Radioactive Waste Disposal Section).

3.1.12.5 Materials Management

DOE has programs and procedures in place to procure and manage hazardous and nonhazardous chemicals and materials (DIRS 104842-YMP 1996, all). By using these programs, the Department is able to minimize the number and quantities of hazardous chemicals and materials stored at the Yucca Mountain site and maintain appropriate storage facilities.

The chemical and material inventory report (DIRS 148107-Dixon 1999, pp. 4, 4a, and 5) for the Nevada State Fire Marshal's office lists 33 hazardous chemicals and materials. The Yucca Mountain Project holds many of these in small quantities, and it stores sulfuric acid in larger quantities [above the threshold planning quantity of about 450 kilograms (1,000 pounds) that requires emergency planning]. Most of the sulfuric acid is in lead-acid batteries (DIRS 148107-Dixon 1999, all). In addition, the Yucca Mountain Site Characterization Project stores the following hazardous chemicals in large amounts [exceeding 4,500 kilograms (10,000 pounds)]: propane, gasoline, cement, and lubricating and hydraulic oils. The project does not store highly toxic substances in quantities higher than the State of Nevada reporting thresholds (DIRS 148107-Dixon 1999, p. 1).

3.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs each Federal agency "to make achieving environmental justice a part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations."

DOE has identified the minority and low-income communities in the Yucca Mountain region of influence, which consists of Clark, Lincoln, and Nye Counties in southern Nevada. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (DIRS 105004-CRWMS M&O 1999, all) is the basis for information in this section.

ENVIRONMENTAL JUSTICE TERMS

Minority: Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.

Low income: Below the poverty level as defined by the Bureau of the Census.

To identify minority and low-income communities in the region of influence, DOE analyzed Bureau of the Census population designations called *block groups*. DOE pinpointed block groups where the percentage of minority or low-income residents is meaningfully greater than average. For environmental justice purposes, the pinpointed block groups are minority or low-income communities. This EIS considers whether activities at Yucca Mountain could cause disproportionately high and adverse human health or environmental effects to those communities.

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Minority: Hispanic, Black, Asian/Pacific Islander, American Indian/Eskimo, Aleut, and other non-white person.

Low income: Below the poverty level as defined by the Bureau of the Census.

3.1.13.1 State of Nevada

Minority persons comprised 21 percent of the population in Nevada in the 1990 census (DIRS 103118-Bureau of the Census 1992, Table P8; DIRS 103119-Bureau of the Census 1992, Table P12). In the 2000 Census, minority persons comprised 35 percent of the population of Nevada (DIRS 156909-Bureau of the Census 2001, p. 1 of Table DP-1; Nevada). It should be noted, however, that between the 1990 Census and the 2000 Census, changes in the Bureau of the Census definitions modified previous race and ethnic categories and for the first time permitted citizens to identify themselves as belonging to more than one category. The Bureau's *Overview of Race and Hispanic Origin*, a Census 2000 Brief issued in March 2001, stated (DIRS 157135-Bureau of the Census 2001, all):

> *Because of these changes, the Census 2000 data on race are not directly comparable with data from the 1990 census or earlier censuses. Caution must be used when interpreting changes in racial composition of the U.S. population over time.*

The environmental justice analysis considered the potential for disproportionately high and adverse impacts on two portions of the overall population—minority communities and low-income communities. While 2000 Census data concerning minority communities in Nevada was available at the block level in time for the Final EIS analysis, comparable 2000 Census data on low-income communities was not. The Final EIS presents 2000 Census data at the block level on minority communities and 1990 Census data at the block group level on low-income communities. This data is the most up-to-date information available for each.

As a consistent criterion for identifying minority and low-income blocks and block groups, DOE employed a 10-percent threshold, meaning that the environmental analysis focused on blocks and block groups in Nevada having a 10-percent or greater minority population or low-income population than the State averages. DOE adopted the 10-percent threshold for the Draft EIS from a 1995 Nuclear Regulatory Commission document, *Interim NRR Procedure for Environmental Justice Reviews* (DIRS 103426-NRC 1995, all). This threshold is consistent with the recent revision of the Nuclear Regulatory Commission's guidance on environmental justice (DIRS 157276-NRC 1999, all).

The environmental justice analysis identified minority communities at the Bureau of the Census block level and low-income communities at the Bureau of the Census block group level. Figure 3-27 shows blocks in the State of Nevada in which 45 percent or more of the population consists of minority persons, according to the 2000 Census. The difference between block level and block group level can be seen in comparing Figure 3-27 to Figure 3-28, which identifies low-income communities at the block group level. The block is a finer resolution; the block group presents the criterion over an aggregate of blocks. Both types of data sets have advantages over the other, depending on the specific analysis being performed. Census blocks can be quite large in rural areas where population density is low because they are associated with a relatively small number of persons. In populous areas such as Las Vegas, the block size is usually quite small and is not clearly depicted on a scale such as that shown in Figure 3-27. Figure 3-29 shows blocks in the Las Vegas area with 45 percent or higher minority population.

The 1990 census characterized about 10 percent of the people in Nevada as living in poverty (DIRS 103120-Bureau of the Census 1992, Table P117). The Bureau of the Census characterizes persons in poverty as those whose income is less than a statistical poverty threshold, which is based on family size and the ages of its members. In the 1990 census the threshold for a family of four was a 1989 income of $12,674 (DIRS 102119-Bureau of the Census 1995, Section 14). In this environmental impact statement, low-income communities are those block groups in which the percentage of persons in poverty equals or exceeds 20 percent as reported by the Bureau of the Census. Figure 3-28 shows low-income communities in Nevada by block group. Figure 3-30 shows low-income communities in the Las Vegas area by block group.

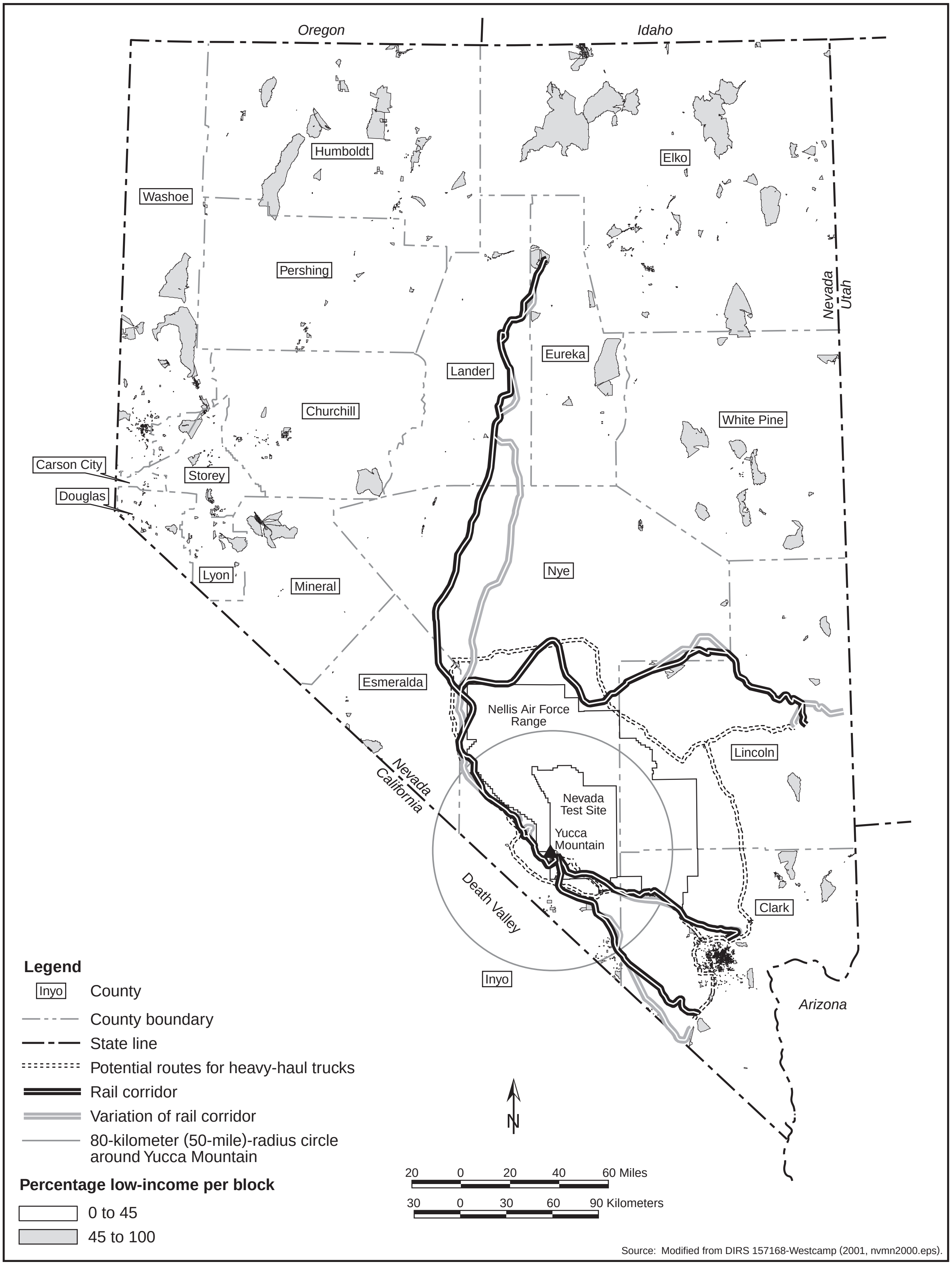

Figure 3-27. Minority communities in Nevada.

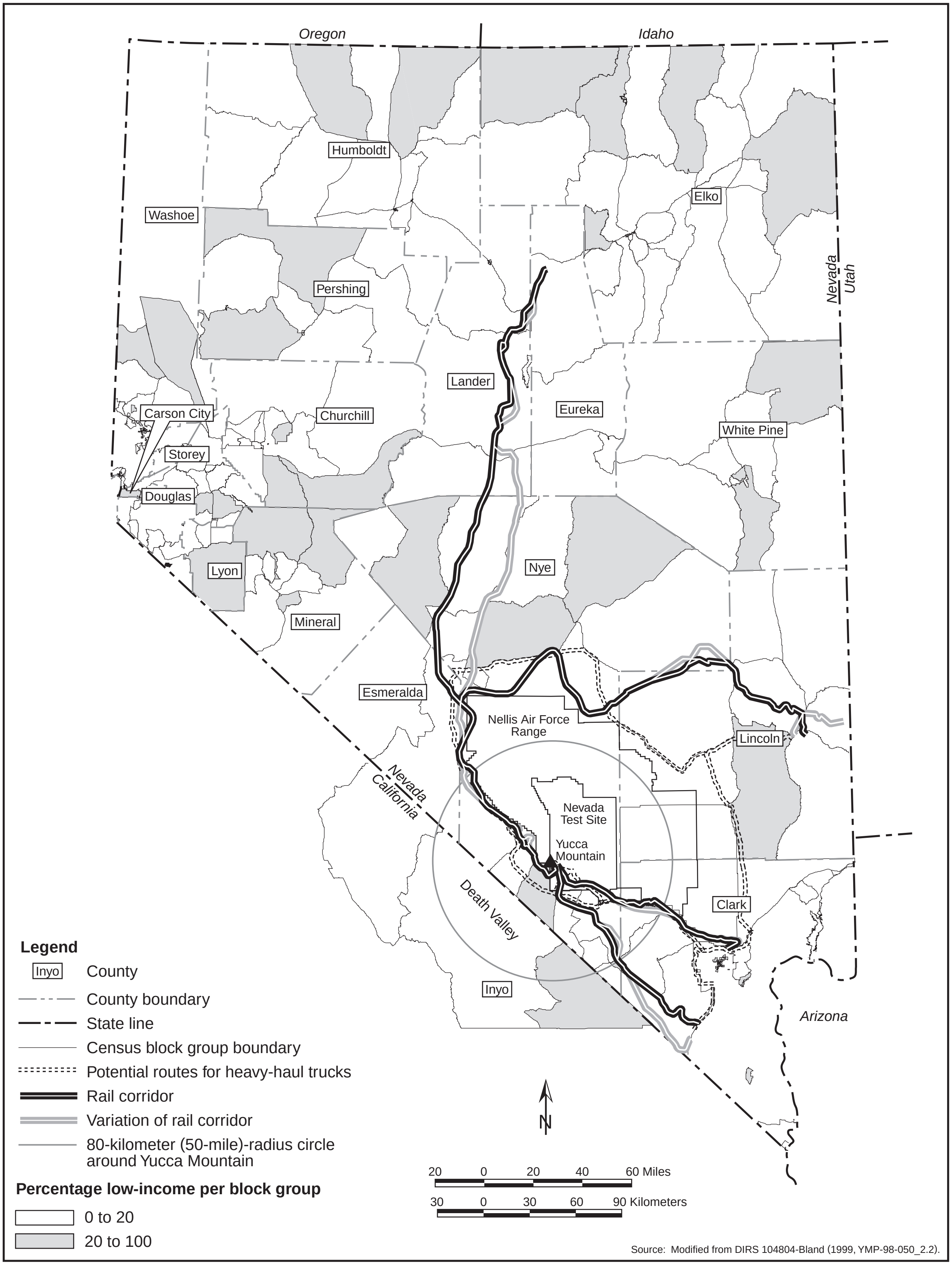

Figure 3-28. Low-income communities in Nevada.

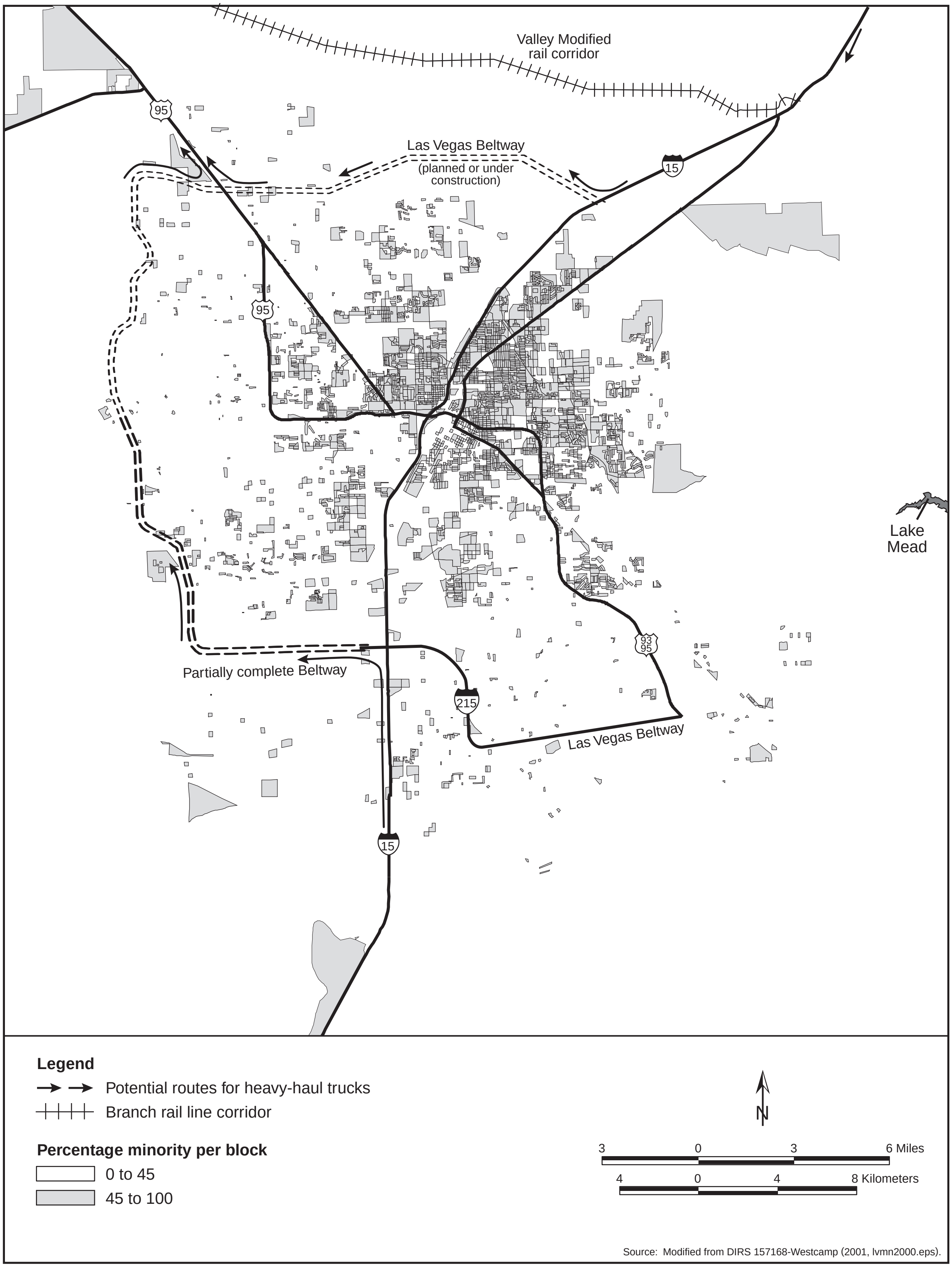

Figure 3-29. Minority census blocks in the Las Vegas metropolitan area.

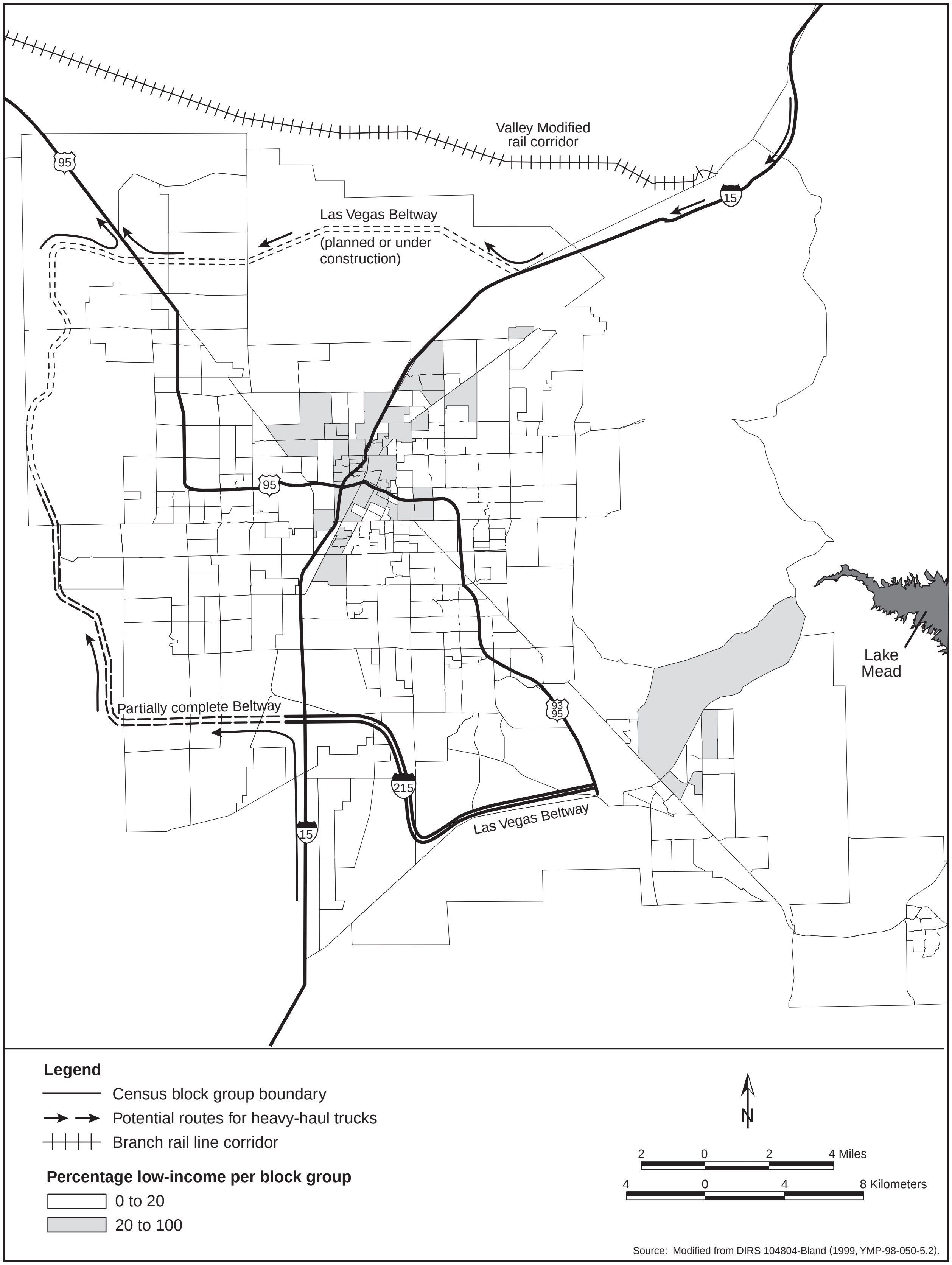

Figure 3-30. Low-income census block groups in the Las Vegas metropolitan area.

3.1.13.2 Clark County

In 2000, the minority population of Clark County was about 548,000 persons, or 40 percent of the *total population* (DIRS 156909-Bureau of the Census 2001, p. 3 of Table DP-1; Clark County). In 1990, a total of about 80,000 residents, or 11 percent of the Clark County population, was characterized as living in poverty (DIRS 103123-Bureau of the Census 1992, Table P117).

3.1.13.3 Lincoln County

In 2000, the Lincoln County minority population consisted of about 450 persons, or 10 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 10 of Table DP-1; Lincoln County). In 1990, 500 persons, or 14 percent of the population, were characterized as living in poverty (DIRS 103127-Bureau of the Census 1992, Table P117).

3.1.13.4 Nye County

In 2000, the Nye County minority population was about 5,000 persons, or 15 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 13 of Table DP-1; Nye County). In 1990, there were 2,000 persons, or 11 percent of the population, characterized as living in poverty (DIRS 103131-Bureau of the Census 1992, Table P117).

3.1.13.5 Inyo County, California

One block group with a low-income population located in the area of the Stewart Valley in Inyo County, California, lies partly within the 80-kilometer (50-mile) air quality region of influence for the repository (Figure 3-25). DOE performed additional review, including a ground survey, and concluded that low-income persons living in the block group would be likely to live outside the 80-kilometer region of influence for the repository.

3.2 Affected Environment Related to Transportation

This section describes the existing (or baseline) environmental conditions along the candidate rail corridors and truck (legal-weight and heavy-haul) routes to the Yucca Mountain site. The EIS treats these corridors and routes as current analytical tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice (would) because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

DOE has made revisions to this section since the publication of the Draft EIS to present newly acquired information that contributes to an improved (or updated) understanding of the potentially affected environment, to address more specifically the affected environment along the rail corridor variations in Nevada, and to include information and suggestions for improvement provided through public comment on the Draft EIS and the Supplement to the Draft EIS. The more significant changes occur in the Nevada Transportation section (Section 3.2.2) and particularly in the discussion of candidate rail corridors (Section 3.2.2.1). Key changes to the Final EIS that deal with affected environment for transportation are summarized in the following:

- Incorporated updates to the land use discussions based on actions since the Draft EIS, including land transfers to the Timbisha Shoshone Tribe for establishment of new reservation; and to Clark County for the development of the Ivanpah Valley Airport and the Apex Industrial Park.

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- Incorporated updates to the land use discussions based on actions since the Draft EIS, including land transfers to the Timbisha Shoshone Tribe for establishment of new reservation; and to Clark County for the development of the Ivanpah Valley Airport and the Apex Industrial Park.

- Improved descriptions of land use and aesthetics as a result of the collection of additional information, including perspectives gained from a ground survey of the potential rail corridors.
- Expanded hydrology discussions, primarily by reference to Appendix L, to include results of an effort to compile information on 100-year flood zones along the rail corridors and their variations.
- Augmented the biological resources discussion for potential Nevada rail corridors to biological resources and soils by adding a new soils section to describe several pertinent soil characteristics and their presence along the rail corridors and their variations.
- Expanded cultural resources discussions to incorporate results of an effort to collect and evaluate additional baseline data for the Nevada Transportation for the rail corridors and the heavy-haul truck routes.
- Updated baseline socioeconomic data to incorporate information from the 2000 Census and, as appropriate, information from the State Demographer and local government agencies.
- Expanded the noise discussion to address background levels of ground vibration along both the rail corridors and the heavy-haul truck routes.
- Updated and refined the environmental justice methodology described for candidate rail corridors, including the incorporation of more detailed maps (in Appendix J) of minority populations.
- Expanded information presented in the land use, hydrology (surface-water and groundwater), biological resources, and cultural resources discussions to address more specifically applicable variations to each of the rail corridors.

3.2.1 NATIONAL TRANSPORTATION

The loading and shipping of spent nuclear fuel and high-level radioactive waste would occur at 72 commercial and 5 DOE sites in 37 states. Transport of these materials to the Yucca Mountain site could involve trains, legal-weight trucks, heavy-haul trucks, and barges; the trains and trucks would travel on the Nation's railroads and highways. This includes existing railroads and highways in Nevada up to a point of departure to specific Nevada routes described in Section 3.2.2. Barges and heavy-haul trucks would be used for short-distance transport of spent nuclear fuel from storage sites to nearby railheads. (Heavy-haul trucks could also be used for Nevada transportation, as discussed in Section 3.2.2.2.)

The national transportation of spent nuclear fuel and high-level radioactive waste (including transportation in Nevada to a point of departure to a specific Nevada transportation route) would use existing highways and railroads and would represent a small fraction of the existing national highway and railroad traffic [less than 1 percent (0.006 percent) of truck miles per year or 0.007 percent of railcar miles per year (DIRS 150989-BTS 1998, p. 6)]. Because no new land acquisition and construction would be required to accommodate these shipments, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes.

The region of influence for public health and safety along existing transportation routes is 800 meters (0.5 mile) from the centerline of the transportation rights-of-way and from the boundary of railyards for incident-free (nonaccident) conditions. The region of influence extends to 80 kilometers (50 miles) to address potential human health and safety impacts from accident scenarios.

DOE used HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all) computer models to derive representative highway and rail routes, respectively, for shipping spent nuclear fuel and high-level radioactive waste. In addition to identifying routes that were used in the analysis, these models were used to estimate population densities along routes in states other than Nevada based on the 1990 Census. The HIGHWAY model identified highway routes between the commercial and DOE generator sites and the proposed repository that would meet the requirements of U.S. Department of Transportation regulations; there are no corresponding Federal regulations that constrain the routing of rail shipments. The analysis used population densities along the highway and rail routes to estimate human health impacts and consequences of transportation. Except in Nevada, the analysis accounted for growth in populations along routes by increasing impacts based on Bureau of the Census forecasts of state populations in 2025, population reported by the 2000 Census for each state, and extrapolation of population growth along routes to 2035. For routes in Nevada, DOE used a Geographic Information System and 1990 census data to develop an initial estimate of the populations within 800 meters (0.5 mile) along highways, commercial rail lines, and the potential corridors for a proposed branch rail line. The analysis of health and safety impacts accounted for growth in populations along Nevada routes by increasing impacts based on forecasts of population growth in Nevada counties using the REMI computer program. The analysis using the REMI program used population growth forecasts provided by Clark County, Nye County, and the State of Demographer and census data for each county provided by the 2000 Census to estimate populations in Nevada in 2035.

3.2.1.1 Highway Transportation

USE OF REPRESENTATIVE ROUTES IN IMPACT ANALYSIS

At this time, prior to approval of the site for development and operation of a repository and years prior to a possible first shipment, the actual routes that would be used to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain have not been identified. However, the highway and rail routes used for analysis in this EIS are representative of routes that could be used. The highway routes conform to U.S. Department of Transportation regulations (49 CFR 397.101). These regulations, developed for transportation of Highway Route Controlled Quantities of Radioactive Materials, require such shipments to use preferred routes that would reduce the time in transit. A preferred route is an Interstate System highway, bypass, or beltway, or an alternative route designated by a state routing agency. Alternative routes could be designated by states and tribes under U.S. Department of Transportation regulations (49 CFR 397.103) that require consideration of the overall risk to the public and prior consultation with local jurisdictions and other states. Federal regulations do not restrict the routing of rail shipments. However, for the analysis, as discussed in Appendix J, Section J.1.1.3 of the EIS, DOE assumed routes for rail shipments that would provide expeditious travel, use of high quality track, and the minimum number of interchanges between railroads.

Highway (legal-weight truck) transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use local highways near the commercial and DOE sites and near Yucca Mountain, Interstate Highways, Interstate bypasses around metropolitan areas, and preferred routes designated by state routing agencies where applicable. DOE used the HIGHWAY computer program (DIRS 104780-Johnson et al. 1993, all) to derive representative highway routes for shipping spent nuclear fuel and high-level radioactive waste between the commercial and DOE sites and the proposed repository. Population density distributions, with the exception of those routes in Nevada, were calculated along the routes to support human health risk consequences. DOE used a Geographic Information System to calculate the population density distributions for routes in Nevada.

Appendix J describes the representative routes used for analysis in this EIS. Actual transportation mode and routing decisions would be made on a route-specific basis during the transportation planning process, if a decision was made to build a repository at Yucca Mountain.

3.2.1.2 Rail Transportation

In most cases, rail transportation of spent nuclear fuel and high-level radioactive waste would originate on track operated by shortline rail carriers that provide service to the commercial and DOE sites. At railyards near the sites, shipments in general freight service would switch from trains and tracks operated by the shortline rail carriers to trains and tracks operated by national mainline railroads. Figure 2-23 in Chapter 2 shows existing mainline track for the major U.S. railroads that DOE could use for shipments to Nevada. This interlocking network has about 290,000 kilometers (180,000 miles) of track that link the major population centers and industrial, agricultural, and energy and mineral resources of the Nation (DIRS 103069-AAR 1996, all). With the exception of shortline regional railroads that serve the commercial and DOE sites, DOE anticipates that cross-country shipments would move on mainline railroads.

Rail transportation routing of spent nuclear fuel and high-level radioactive waste shipments is not regulated by the U.S. Department of Transportation. The routes used in this EIS were derived from the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all). The identification for purposes of analysis of these routes was based on current railroad practices using existing routes. Appendix J describes the rail routes used in this EIS analysis.

3.2.1.3 Barge and Heavy-Haul Truck Transportation

Commercial sites that do not have direct rail service could ship spent nuclear fuel on heavy-haul trucks or barges to nearby railheads. Heavy-haul trucks would use local highways to carry the spent nuclear fuel to a nearby railhead for transfer to railcars for transport to Nevada. Barge shipments would use navigable waterways accessible from the nuclear plant site. These shipments would travel on the waterways to nearby railheads for transfer to railcars for transport to Nevada. Appendix J describes the heavy-haul truck and barge routes used in this EIS analysis.

3.2.2 NEVADA TRANSPORTATION

Shipments of spent nuclear fuel and high-level radioactive waste arriving in Nevada would be transported to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. The discussion of national transportation modes and routes in Section 3.2.1 addresses the affected environment for legal-weight truck transport from commercial and DOE facilities to the Yucca Mountain site, including travel in Nevada. This section addresses the affected environment in Nevada for candidate rail corridors, heavy-haul truck routes, and potential locations for an intermodal transfer station that DOE could use for transporting spent nuclear fuel and high-level radioactive waste and that would require new construction.

Legal-weight truck shipments in Nevada would use existing highways and would be a very small fraction of the total traffic [less than 0.5 percent of commercial vehicle traffic on U.S. Highway 95 in southern Nevada (DIRS 103405-NDOT 1997, p. 9; DIRS 104727-Cerocke 1998, p. 1). Because no new land acquisition and construction would be required to accommodate legal-weight trucks, this EIS focuses on potential impacts to human health and safety and the potential for accidents along the shipment routes from legal-weight truck shipments. Appendix J contains baseline environmental information related to human health and safety and the impacts from accident scenarios.

To allow large-capacity rail cask shipments to the repository, DOE is considering the construction of a new branch rail line or the establishment of heavy-haul truck shipment capability. Sections 3.2.2.1 and 3.2.2.2 describe the existing (or baseline) environment for each of the candidate rail corridors and heavy-haul truck routes and for potential locations for an intermodal transfer station. The locations selected for candidate rail corridor starting points and for a potential intermodal transfer station are all accessible by main rail lines that are currently in operation. National rail transportation would simply involve routings to accommodate the selected starting point for Nevada transportation. DOE would prefer to use a branch rail line to ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

3.2.2.1 Environmental Baseline for Potential Nevada Rail Corridors

This section discusses the environmental characteristics of land areas that could be affected by the construction and operation of a rail line to transport spent nuclear fuel and high-level radioactive waste to the proposed repository. It describes the environmental conditions in five alternative rail corridors—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified. Chapter 2, Section 2.1.3.2, describes these corridors in more detail. Figures 6-15 through 6-19 in Chapter 6 show detailed maps for these corridors.

To define the existing (or baseline) environment along the five proposed rail corridors; DOE has compiled environmental information for each of the following subject areas:

- *Land use and ownership:* The condition of the land, current land-use practices, and land ownership information (Section 3.2.2.1.1)
- *Air quality and climate:* The quality of the air and the climate (Section 3.2.2.1.2)
- *Hydrology:* The characteristics of surface water and groundwater (Section 3.2.2.1.3)
- *Biological resources:* Important biological resources (Section 3.2.2.1.4)
- *Cultural resources:* Important cultural resources (Section 3.2.2.1.5)
- *Socioeconomic environments:* The existing socioeconomic environments (Section 3.2.2.1.6)
- *Noise and vibration:* The existing noise environments (Section 3.2.2.1.7)
- *Aesthetics:* The existing visual environments (Section 3.2.2.1.8)
- *Utilities, energy, and materials:* Existing supplies of utilities, energy, and materials (Section 3.2.2.1.9)
- *Environmental justice:* The locations of low-income and minority populations (Section 3.2.2.1.10)

A Geographic Information System provided population distributions for differing population zones (urban, rural, suburban) along the candidate rail corridors. This approach, as discussed in Section 3.2.1, differs from the analysis for national transportation, which used the INTERLINE computer program (DIRS 104781-Johnson et al. 1993, all) (see Chapter 6 for more detail).

DOE expects waste quantities generated by rail line construction and operation to be minor in comparison to those from repository construction and operation. As such, no discussion of existing waste disposal infrastructure along the routes is provided.

DOE evaluated the potential impacts of the implementing alternatives in regions of influence for each of the subject areas listed above. Table 3-35 defines these regions, which are specific to the subject areas, in which DOE could reasonably expect to predict potentially large impacts related to rail line construction and operation. The following sections describe the various environmental baselines for the rail implementing alternatives.

TERMS RELATED TO IMPLEMENTING ALTERNATIVE RAIL LINES

DOE has expanded the discussion of the affected environment in the corridors considered for rail use in this EIS. This includes the use of several terms that have specific meanings in the context of the discussion. In addition to this discussion, DOE has used these terms in the transportation analyses described in Chapter 6 and Appendix J. The following list defines these terms:

Implementing alternative – An action or proposition by DOE necessary to implement the Proposed Action and to enable the estimation of the range of reasonably foreseeable impacts of that action. In other words, an implementing alternative represents a feasible option that DOE could implement based in part on this EIS (for example, the selection of a branch rail line corridor).

The implementing rail alternatives for Nevada transportation are the five corridors—Carlin, Caliente, Caliente-Chalk Mountain, Jean, and Valley Modified—for a new branch rail line:

Corridor – A strip of land in Nevada, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a rail line to transport spent nuclear fuel, high-level radioactive waste, and other material to and from the Yucca Mountain Repository site.

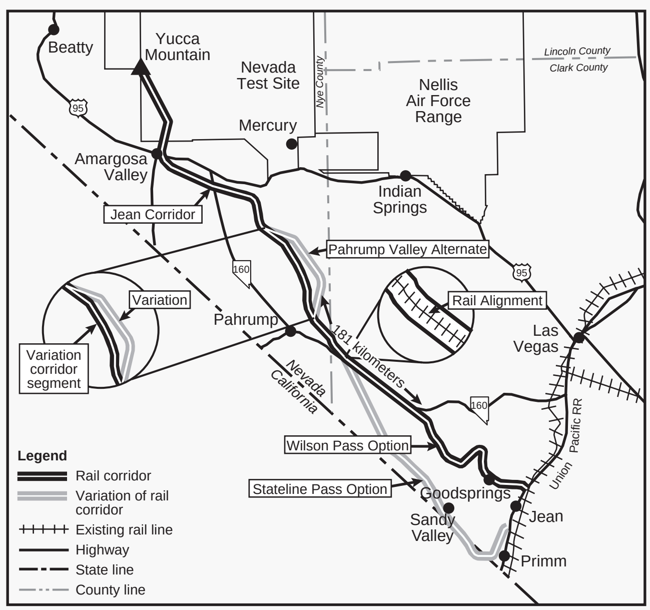
Alignment – The location of a rail line in a corridor. DOE has not determined the final alignment for a branch rail line in any of the candidate rail corridors.

Variation – In this context, a strip of land, approximately 400 meters (0.25 mile) wide, from one point along a corridor to another point on the same corridor that describes a different route. There are three types of variation:

Option – In this context, a variation based on a determination that the location of a corridor segment is essentially equivalent to that of another option, considering environmental and engineering factors.

Alternate – In this context, a variation in the location of a corridor segment to mitigate a potential adverse environmental or engineering factor.

Connection/Connector – In this context, a short variation of a corridor that connects a corridor to a commercial railroad or that connects an alternate or option of a corridor to the corridor.



DOE believes that this EIS provides the environmental impact information necessary to select a rail corridor. However, before DOE could select an alignment in that corridor, it would have to conduct additional field surveys; State, local, and tribal government consultations; engineering and environmental analyses; and National Environmental Policy Act reviews.

Table 3-35. Regions of influence for rail implementing alternatives.

Subject area	Region of influence
Land use and ownership	Land areas that would be disturbed or whose ownership or use would change as a result of construction and use of branch rail line
Air quality and climate	The atmosphere in the vicinity of sources of criteria pollutants that would be emitted during branch rail line construction and operations, and particularly the Las Vegas Valley for implementing alternatives where constructing and operating a branch rail line could contribute to the level of carbon monoxide and PM_{10} already in nonattainment of standards.
Hydrology	*Surface water:* areas near where construction would take place that would be susceptible to erosion, areas affected by permanent changes in flow, and areas downstream of construction that could be affected by eroded soil or potential spills of construction contaminants
	Groundwater: aquifers that would underlie areas of construction and operations and aquifers that might be used to obtain water for construction
Biological resources	Habitat, including jurisdictional wetlands and riparian areas inside the 400-meter-wide[a] corridors; habitat, including jurisdictional wetlands outside the corridor that could be disturbed by rail line construction and operations; habitat, including jurisdictional wetlands, and riparian areas that could be affected by permanent changes in surface-water flows; migratory ranges of big game animals that could be affected by the presence of a branch rail line
Cultural resources	Lands inside the 400-meter-wide rail corridors
Socioeconomic environments	Clark, Lincoln, Nye and other counties that a potential branch rail line would traverse
Public health and safety	800 meters[b] on each side of the rail line for incident-free transportation, 80-kilometer[c] radius for potential impacts from accident scenarios
Noise and vibration	Inhabited commercial and residential areas where noise and vibration from rail line construction and operations could be a concern
Aesthetics	The landscapes along the potential rail corridors with aesthetic qualities that could be affected by construction and operations
Utilities, energy, and materials	Local, regional, and national supply infrastructure that would be required to support rail line construction and operations
Environmental justice	Locations of minority, low-income, and Native American populations along the rail implementing alternatives; includes the regions of influence for each of the preceding individual subject or impact areas

a. 400 meters = 0.25 mile.
b. 800 meters = 0.5 mile.
c. To convert kilometers to miles, multiply by 0.62137.

3.2.2.1.1 *Land Use and Ownership*

Table 3-36 summarizes the estimated land commitment and current ownership or control of the land in each rail corridor. It addresses both the representative corridor and the range of values applicable to corridor variations. Public lands in and near the corridors are used for a variety of activities including grazing, mining, and recreation. All public land in the Caliente, Carlin, Jean, and Valley Modified Corridors is open to mining and mineral leasing laws and offroad vehicle use, with restrictions in some areas (DIRS 101504-BLM 1979, all; DIRS 101523-BLM 1994, all; DIRS 103080-BLM 1999, all). The rail corridor descriptions, unless otherwise noted, are from DIRS 104993-CRWMS M&O (1999, all), DIRS 101214-CRWMS M&O (1996, all) and DIRS 104560-YMP (1998, all).

Table 3-36. Land ownership for the candidate rail corridors.[a]

Corridor	Land in corridor: Totals (km²)[b,c]	Ownership or control (percent)[d]: BLM	USAF	DOE	Private	Tribal	Other
Representative corridors							
Caliente	205	188 (92)	11 (5)	4.6 (2)	0.9 (<1)	0	0
Carlin	208	179 (86)	11 (5)	4.6 (2)	14 (7)	0	0
Caliente-Chalk Mountain	138	78 (57)	22 (16)	38 (27)	0.8 (<1)	0	0
Jean	72	60 (83)	0	8.5 (12)	3.5 (5)	0	0
Valley Modified	63	34 (53)	7 (11)	21 (32)	0.2 (<1)	0	1.8 (3)
Ranges for corridors with variations (all in km²)							
Caliente	205 - 221	188 - 216	0 - 11	4.6	0.9 - 2.5	0 - 1.6	0
Carlin	205 - 218	177 - 201	0 - 11	4.6	7.3 - 1.5	0 - 1.6	0
Caliente-Chalk Mountain	138 - 153	77 - 89	22	32 - 38	0.8 - 1.1	0	0
Jean	72 - 82	60 - 69	0	8.5	0.1 - 3.5	0	0
Valley Modified	63 - 65	30 - 37	3.6 - 7.5	21	0 - 0.2	0	1.7 - 4.1

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert square kilometers (km²) to acres, multiply by 247.1.
c. Totals might differ from sums due to rounding.
d. Bureau of Land Management (BLM) property is public land administered by the Bureau; U.S. Air Force property is the Nellis Air Force Range; DOE property is the Nevada Test Site; tribal land is the Timbisha Shoshone Trust Lands; and the Other designation is the Desert National Wildlife Range managed by the Fish and Wildlife Service.

Caliente. Most of the lands associated with the Caliente Corridor (92 percent) are public lands managed by the Ely, Battle Mountain, and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (DIRS 101523-BLM 1994, all), the *Department of the Interior Final Environmental Impact Statement, Proposed Domestic Livestock Grazing Management Program for the Caliente Area* (DIRS 101504-BLM 1979, all), the *Final Legislative Environmental Impact Statement, Timbisha Homeland* (DIRS 154121-DOI 2000, all) the *Caliente Management Framework Plan Amendment and Environmental Impact Statement for the Management of Desert Tortoise Habitat* (DIRS 103080-BLM 1999, all), and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

The U.S. Air Force uses about 5 percent of the lands associated with the Caliente Corridor. The corridor crosses the western boundary of the Nellis Air Force Range near Goldfield and again northeast of Scottys Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in the *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all).

DOE uses about 2 percent of the lands associated with the Caliente Corridor. The corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in the *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all).

Less than 1 percent of the land associated with the Caliente Corridor is private. The corridor crosses private land near Caliente.

The Caliente Corridor (Chapter 2, Figure 2-26) begins in Lincoln County, at an existing section of the Union Pacific Railroad at Eccles, and moves north across mostly Bureau of Land Management lands toward U.S. 93 near Comet Siding, which is south of Panaca. Two alternate sections are being evaluated as the beginning point of this corridor. One is west of a section of the Union Pacific Railroad at Crestline [approximately 3.2 kilometers (2 miles) west of the Dixie National Forest]. From that point it continues west across Bureau of Land Management lands to the point south of Panaca where it joins the main corridor. The other alternate section originates at the Town of Caliente. This section travels north along an existing Union Pacific rail line, running parallel to U.S. 93 to the intersection with the main rail corridor in the same area just south of Panaca. Although the 1990 Bureau of Land Management Master Title Plats indicate that the former Union Pacific right-of-way remains active, the right-of-way ownership for the abandoned rail bed is not clear. Each of these starting sections passes through Meadow Valley Wash. Approximately 3.2 kilometers (2 miles) north of this corridor (just north of Panaca) is the Cathedral Gorge State Park.

The section from Caliente has seen more development and has more inhabitants than the Crestline and the Eccles corridor initiation locations. A utility transmission line extends from Caliente to an area west of Panaca. The Eccles, Caliente, and Crestline Options cross private lands. There are numerous houses, farms, and ranches north of Caliente and extending toward Panaca. Areas of ponded water and streams associated with the Meadow Valley Wash occur through this area along the eastern side of U.S. 93 (which in this area is part of the State Scenic Byway). The Crestline and Caliente Options cross two rights-of-way: one for U.S. 93 and one telephone; the Eccles Option does not cross any rights-of-way. Past the area where the alternate starting sections converge, the corridor passes west on Bureau of Land Management lands near Bennett Springs Road, moves through the Highland Range in the area of Bennett Pass, and continues across Bureau land in the northern section of the North Pahroc Range. Through this section the corridor passes through two pipeline, one telephone, and two road rights-of-way, and east of a wilderness study area. The corridor then moves through Bureau lands west of Nevada State Route 318, along the Lincoln/Nye County line north of the Seaman Range. The corridor passes just north of the Weepah Springs Wilderness Study Area located in the vicinity of Timber Mountain in Lincoln County.

The rail corridor splits in the area of Timber Mountain Pass, with a possible section (the White River Alternate) going north of the Seaman Range into the White River Valley and then passing back to the south and west along and through the Golden Gate Range. The corridor continues on Bureau of Land Management lands in a general southwesterly direction and back into Lincoln County through Garden and Sand Spring Valleys. In Garden Valley, the corridor and the Garden Valley Alternate wind around private land. The corridor crosses one road and one pipeline right-of-way, and five oil or gas leases. The Garden Valley Alternate crosses two road and two pipeline rights-of-way. The corridor continues on Bureau land and passes generally to the southwest into Nye County, to land around the Reveille Range north of the Cedar Pipeline Ranch. It then turns north toward Warm Springs, passing between the Reveille and Kawich Ranges, and passing to the east of the Eden Creek Ranch. As the corridor passes between the southern portion of the Kawich and South Reveille Ranges, it passes just east of the Kawich Wilderness Study Area and encroaches on the South Reveille Wilderness Study Areas. The corridor turns southwest again toward the Nellis Air Force Range, passing the Town of Golden Arrow and the Reeds Ranch, which is just north of the Nellis Range. Also north of the Nellis Range, the Kawich Range contains several ranches and small towns and communities, as well as abandoned and current mining operations.

The Toiyabe National Forest is approximately 6.4 kilometers (4 miles) northwest of the corridor as it passes north of the Kawich Range. Numerous two-track roads surround the Kawich Range providing access to grazing allotments, mining claims, and recreational areas. The corridor then passes along the northern boundary of the Nellis Air Force Range through Ralston Valley. From the merging of the Garden Valley Alternate to the western boundary of the Nellis Range, the corridor crosses or travels along two Bureau of Land Management utility corridors. The corridor also crosses two road, two pipeline, and two powerline rights-of-way. It then turns south along the western boundary of the Nellis Range. Both gravel and two-track roads are present in that area, and throughout the remainder of the corridor, with many entering the Nellis Range.

The corridor splits east of the Town of Goldfield, with the alternate segment going west of Blackcap Mountain, through Bureau of Land Management land and two parcels of private property to the south along the Nye/Esmeralda County line. The corridor traverses a section on the Nellis Air Force Range. The corridor and the alternate segment rejoin in Bureau land along the Nye/Esmeralda County line near the Town of Ralston.

The corridor proceeds south until it splits again around the Town of Scottys Junction in Nye County. One segment, the Bonnie Claire Alternate, passes to the west, crossing U.S. 95 and State Route 267. This western segment passes through 11 square kilometers (2,800 acres) of formerly Bureau of Land Management lands transferred to the Timbisha Shoshone. This parcel of land is being proposed for Tribal economic development (tourism) and Tribal housing (DIRS 154121-DOI 2000, all). In addition to rights-of-way for U.S. 95 and State Route 267, the Bonnie Claire Alternate crosses two powerline and one telephone rights-of-way. It passes through a portion of private land south of U.S. 95. The corridor crosses into the Nellis Air Force Range for a short distance northeast of Scottys Junction before moving back into Bureau of Land Management land. The alternate segment merges with the corridor, which then follows U.S. 95 toward the Town of Beatty, which it passes to the east. A minor segment, the Oasis Alternate, goes slightly farther east of Beatty before merging with the corridor. A little farther to the southeast, the Beatty Wash Alternate then diverges for a short distance until it realigns with the corridor and crosses a Bureau of Land Management utility corridor several times.

Death Valley National Park, west of Beatty at the point closest to the rail corridor, is approximately 11 kilometers (7 miles) to the west. The area surrounding Beatty and extending southeast toward Amargosa Valley has several small towns and numerous current and historic mining operations. There are also campgrounds along U.S. 95. The corridor bypasses most of these areas by moving between Beatty and the Nellis Air Force Range. It continues generally to the south and enters DOE property west of Yucca Mountain and north of the Town of Amargosa Valley.

Carlin. Most of the lands associated with the Carlin Corridor (about 86 percent) are public lands managed by the Battle Mountain and Las Vegas offices of the Bureau of Land Management. Detailed information on land use is available in the *Draft Shoshone-Eureka Resource Management Plan and Environmental Impact Statement* (DIRS 103077-BLM 1983, all), the *Proposed Tonopah Resource Management Plan and Final Environmental Impact Statement* (DIRS 101523-BLM 1994, all), the *Final Legislative Environmental Impact Statement, Timbisha Homeland* (DIRS 154121-DOI 2000, all) and the *Proposed Las Vegas Resource Management Plan and Final Environmental Impact Statement* (DIRS 103079-BLM 1998, all).

The U.S. Air Force uses about 5 percent of the lands associated with the Carlin Corridor. The combined Carlin/Caliente Corridor crosses into the western portion of the Nellis Air Force Range near Goldfield and again northeast of Scottys Junction. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 2 percent of the lands associated with the Carlin Corridor. The combined Carlin/Caliente Corridor enters the Nevada Test Site south of Beatty. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

About 7 percent of the land associated with the Carlin Corridor is private. The corridor crosses private roads in the northern part of the route, from Beowawe through Crescent Valley.

The Carlin Corridor (Chapter 2, Figure 2-26) begins near the Town of Beowawe in Eureka County, at an existing Union Pacific Railroad line. The corridor moves south along Crescent Valley through a mix of private and Bureau of Land Management lands that extend south of the Town of Crescent Valley, near the Dean Ranch. The corridor crosses numerous gravel and two-track roads, most of which lead to adjoining valleys, ranches, or grazing allotments in Crescent Valley and in the adjacent mountains. The corridor runs east of State Route 306 and continues south toward the Dean Ranch.

Just north of the Dean Ranch and east of State Route 306, the corridor splits. The corridor itself crosses State Route 306 to the west and continues south and west of the Dean Ranch, and the alternate segment travels south and east of the Dean Ranch. The two rejoin south of the ranch on Bureau of Land Management land near the Cortez Airstrip west of the Cortez Gold Mine. An expansion of the Cortez Gold Mine operations, recently approved by the Bureau of Land Management (DIRS 155095-BLM 2000, all), involves the disturbance of an additional 18 square kilometers (4,450 acres) of public lands. This action includes expansion of an existing open pit, extension of process solution pipelines, modifications to the existing road between Gold Acres and the Cortez milling facility, the increase of waste rock and tailings facilities, and a pipeline right-of-way from the mine to the Dean Ranch for supplying water to the ranch. The corridor passes from Eureka County into Lander County near the Dean Ranch. Through Crescent Valley it crosses private lands and two road, one powerline, and two telephone rights-of-way. One of the road rights-of-way runs from the Gold Acres Mine to the Cortez Mine milling facility. The Crescent Valley Alternate crosses private lands, one right-of-way, and another road with no right-of-way listed. Near the Town of Gold Acres, the Gold Acres Mine and its spoils pile are the dominant features in the valley. There are numerous active and abandoned mine sites in the area of the Shoshone Range and the Cortez Mountains. Also in this area are several small towns and numerous ranches in the Crescent Valley and Grass Valley.

The corridor passes east and south of the Cortez Airstrip and through a northern portion of the Toiyabe Range that is not part of the Toiyabe National Forest. In this section of the Toiyabe Range, there is a split in the corridor for engineering design reasons. The corridor passes into Grass Valley west of Hot Springs Point, extending to the south, east of the Cowboy Rest Ranch. It follows the western side of the valley until it splits north of the Grass Valley Ranch. The corridor segment runs west of the Grass Valley Ranch, where it crosses private lands adjacent to Bureau of Land Management lands. Roads connect Grass Valley to the surrounding areas, most of which appear to be two-track roads that extend from main gravel roads in the valley to the mountainous areas on both sides of the valley. Some of these two-track roads might be for recreation, but are probably used to access Bureau grazing or mining allotments in the area. The corridor follows Bureau lands and continues to the south. The alternate segment (the Steiner Creek Alternate) passes to the east of the Grass Valley Ranch, along the western base of the Simpson Park Mountains. The Steiner Creek Alternate passes close to the Simpson Park Wilderness Study Area in Lander County just east of the Grass Valley Ranch. The corridor and alternate segments rejoin near Bates Mountain and continue south through Bureau lands in Rye Patch Canyon, still following the western edge of the Simpson Park Mountains. In this area, the corridor splits again, still on Bureau lands. The corridor and the Rye Patch Alternate diverge to bypass sensitive habitat at Rye Patch Spring. Both cross two road rights-of-way. At this point, the corridor splits into two major variations, the Big Smoky Valley Option and the Monitor Valley Option, both of which run mostly through Bureau lands. Soon after this split, both cross the Nye/Lander County line.

The Big Smoky Valley portion of the corridor begins just south of the Givens Ranch in Rye Patch Canyon and continues south along the eastern side of the valley. U.S. 50, a State Scenic Byway, crosses the Valley from east to west, just to the south of the Givens Ranch. The Lander/Nye County line is approximately 26 kilometers (16 miles) south of U.S. 50. South of the county line, the Big Smoky Valley Alternate crosses three road, one flume, four powerline, and two pipeline rights-of-way, and a Desert Land Entry withdrawal parcel west of the Town of Hadley. It also passes through a Bureau of Land Management utility corridor. The Big Smoky Valley is comprised of Bureau lands and private property. The Bureau lands consist primarily of grazing allotments. The main road, State Route 376, runs along the western side of the valley. Other roads cross the valley, generally running east-west, leading to the National Forest on both sides of the valley and to small communities and public recreation areas. Some of these are Forest Service roads that cross the National Forest and connect with State or other Forest Service roads in adjacent valleys. One of the most frequently used public recreation areas is Peavine Public Campgrounds in the southern part of the Toiyabe National Forest in the Toiyabe Range. There are numerous ranches, most along the western edge of the valley. Small roads (two-tracks) run along the valley floor, generally through grazing allotments. A power line runs along the route, just west of the Town of Millers, and continues north up the valley near Manhattan. In this area, the valley is flanked by the Toquima and Toiyabe Ranges, both of which are part of the Toiyabe National Forest. The southern portion of Big Smoky Valley narrows, and there are many small towns in this portion of the valley, limiting the opportunity to avoid private land.

The corridor passes west of State Route 376 and proceeds to the west of the Round Mountain Golf Course near the Town of Hadley and its airport. The route follows the western edge of the valley and continues to the south near the San Antonio Ranch, running between the Town of Midway Station and the San Antonio Mountains, where there is a large section of private land, most of which probably is associated with mining. The route crosses Secondary State Route 89 and, after crossing into Esmeralda County, continues south across U.S. 95/6 west of Tonopah. It then turns to the southeast toward Nellis Air Force Range, crossing U.S. 95 again and moving south and east of the Town of Klondike, where it joins with the Monitor Valley Alternate.

The Monitor Valley Option runs east from the Rye Patch Canyon area along the Simpson Park Mountains, near the Hicks Summit Petroglyph Recreation Area. It crosses U.S. 50 and extends south into Monitor Valley, generally following Stoneberger Creek and adjacent to a two-track road along the western side of the valley. It then continues through the valley east of Secondary State Route 82 and moves into Nye County, passing east of the Monitor Ranch between Potts and the Toquima Range to the west. Monitor Valley is bounded on both east and west by the Toiyabe National Forest, which includes several wildlife areas, recreation areas, ranches, and small communities. Numerous roads cross the valley, leading through the adjacent mountain ranges or to isolated ranches and grazing allotments. The option remains to the east of Secondary State Route 82, continuing south to the community of Belmont, where the valley narrows, and follows along or just west of Secondary State Route 82. Past Belmont, the option follows Secondary State Route 82 to its intersection with State Route 376 and then continues south through Ralston Valley, crossing U.S. 6 west of the Tonopah Municipal Airport. There is a state prison on the western side of State Route 376, approximately 13 kilometers (8 miles) north of U.S. 6. The option continues south until it rejoins the corridor near the Nye/Esmeralda County line. In Monitor Valley, the option crosses one telephone, two road, and one pipeline rights-of-way. There are two Desert Land Entry parcels between the Town of Hadley and the Nye/Esmeralda County line.

The rejoined corridor and option intersect the Caliente Corridor (as described above) near Mud Lake in the northwest corner of the Nellis Air Force Range before continuing to Yucca Mountain. As with the Caliente Corridor, the Carlin Corridor's Bonnie Claire Alternate passes through an area recently designated for the creation of a section of the Timbisha Shoshone Reservation on lands transferred from the Bureau of Land Management (DIRS 154121-DOI 2000, all).

Caliente-Chalk Mountain. Most of the lands associated with the Caliente-Chalk Mountain Corridor (about 57 percent) are public lands managed by the Ely Office of the Bureau of Land Management. Detailed information on land use is available in DIRS 101504-BLM (1979, all) and DIRS 103080-BLM (1999, all).

The U.S. Air Force uses about 16 percent of the lands associated with the Caliente-Chalk Mountain Corridor. The corridor enters the Nellis Air Force Range west of Rachel, Nevada, and travels south through the range. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 27 percent of the lands associated with the Caliente-Chalk Mountain Corridor. The corridor crosses the northern border of the Nevada Test Site and travels to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

Less than 1 percent of the lands associated with the Caliente-Chalk Mountain Corridor is private. The combined Caliente and Caliente-Chalk Mountain Corridor crosses private lands near Caliente.

The beginning portion of the Caliente-Chalk Mountain Corridor (Chapter 2, Figure 2-26) is the same as the beginning portion of the Caliente Corridor described above. The two corridors and their variations are identical until they reach the area of Sand Spring Valley.

At Sand Spring Valley, the Caliente-Chalk Mountain Corridor splits from the Caliente Corridor and continues on Bureau of Land Management land to pass generally south along the Lincoln/Nye County line. The corridor crosses State Route 375 and enters the Nellis Air Force Range east of Queen City Summit.

The Caliente-Chalk Mountain Corridor continues south just west of Chalk Mountain and into the northern portion of Emigrant Valley. It passes numerous paved and two-track roads through this area. The corridor passes almost due south into the Nevada Test Site. Once inside the Test Site the corridor divides just north of the main infrastructure area. The Orange Blossom Road Option continues generally to the south just east of the infrastructure area in the eastern portion of the Test Site. This option continues southeast of French Peak and then passes generally to the west around infrastructure and just north of Skull Mountain. It continues generally westward, passing infrastructure south of the Calico Hills, crossing Fortymile Wash, and into the proposed repository area. It crosses a power right-of-way twice and a waterline right-of-way. It also crosses Nevada Test Site roads.

The Mercury Highway Option splits from the corridor just north of the large Nevada Test Site infrastructure area. This option turns generally south along the east of the Elena Range through Yucca Flat and the center of the Test Site, crossing roads and bypassing existing infrastructure until it joins with the Orange Blossom Road Option just north of Skull Mountain and continues to the proposed repository site.

The Area 4 Alternate splits from the Mercury Highway Option along the western edge of the Nevada Test Site infrastructure area in the vicinity of Syncline Ridge where it joins with the Tonopah Option. This option crosses the Mercury Highway.

The Mine Mountain Alternate splits from the Area 4 Alternate in the vicinity of Mine Mountain Junction to minimize impacts to cultural sites in the area. It splits for only a short distance and then rejoins the Area 4 Alternate.

The Tonopah Option travels just inside the northern Nevada Test Site boundary westward until it begins to turn to the south along the eastern edge of the Elena Range bypassing Test Site infrastructure areas. The route passes along the western edge of Barren Wash until it strikes westward south of the Calico Hills and continues across Fortymile Wash.

The Caliente-Chalk Mountain Corridor crosses lands in which paved, gravel, and two-track roads are abundant. These roads provide access to grazing and mining allotments and recreational areas on Bureau of Land Management lands. Some roads provide access to recreational areas on State and Federal lands (Humboldt National Forest).

Jean. Most of the lands associated with the Jean Corridor (about 83 percent) are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in DIRS 103079-BLM (1998, all).

DOE uses about 12 percent of the lands associated with the Jean Corridor. The corridor enters the Nevada Test Site near Amargosa Valley traveling north to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

About 5 percent of the land associated with the Jean Corridor is private. The corridor crosses private lands in the Pahrump Valley.

The Jean Corridor consists of the Wilson Pass Option (the corridor) and the Stateline Pass Option starting sections (Chapter 2, Figure 2-26). The Wilson Pass Option begins along the Union Pacific rail line just north of Jean. The corridor extends northwest and runs north of State Route 161, along Bureau of Land Management lands toward Goodsprings, and along the southern edge of the Bird Spring Range. It crosses two pipeline, three road, and two powerline rights-of-way.

The corridor passes through the Bureau of Land Management mining area containing the Bluejay, Snowstorm, and Pilgrim Mines, and runs within about 2 kilometers (1.2 miles) south of the Toiyabe National Forest in the Spring Mountains. The area contains a number of access roads to the mine sights. Several State and access roads associated with the National Forest cross the corridor. The corridor passes just to the south of the National Forest and traverses Wilson Pass along Bureau lands, continuing to the northwest until its intersection with State Route 160. It then continues across a Bureau utility corridor and continues on Bureau lands north of State Route 160 until it intersects the Stateline Pass Option.

The Stateline Pass Option begins in Ivanpah Valley along the Union Pacific rail line south of Jean and just north of Roach Lake, in an area that Clark County is proposing as the location for a cargo airport and other purposes. This option passes through Bureau of Land Management lands, going south through mining areas along the California/Nevada state line and then turns northwest, skirting private land around the Sandy Valley community. It crosses two pipeline, two road/highway, and one powerline and telephone rights-of-way. It also passes near the Stateline Wilderness Area.

Continuing along Bureau of Land Management lands just north of Secondary State Route 16, the Stateline Pass Option crosses State Route 160 to intersect the Jean Corridor east of Pahrump. In the Pahrump vicinity, State roads access the national forests to the north, and there are several tracks and trails in the area.

The corridor then crosses from Clark County into Nye County before splitting, with the corridor passing close to the Town of Pahrump and the Pahrump Valley Alternate passing closer to the Spring Mountains east of Pahrump. The corridor segment crosses several parcels of private property. The alternate segment abuts the Toiyabe National Forest and a Bureau of Land Management utility corridor and then enters the utility corridor. The corridor and alternate segments rejoin near the community of Johnnie, just east of State Route 160. There are several tracks and trails in this area. The corridor continues to the north until it passes just south of U.S. 95, where it turns northwest through Bureau of Land Management land north of the Ash Meadows National Wildlife Refuge [approximately 14 kilometers (9 miles) west of Johnnie].

Continuing to the north across the Amargosa Desert, the corridor crosses State Route 160, several gravel roads, and a number of two-track roads on Bureau of Land Management land. The corridor crosses a Bureau utility corridor, two telephone, and two powerline rights-of-way. It then crosses U.S. 95 and enters Nevada Test Site property northeast of the Town of Amargosa Valley and continues to the proposed repository site at Yucca Mountain.

Valley Modified. About 53 percent of the lands associated with the Valley Modified Corridor are public lands managed by the Las Vegas office of the Bureau of Land Management. Detailed information on land use is available in DIRS 103079-BLM (1998, all).

The U.S. Air Force uses about 11 percent of the lands associated with the Valley Modified Corridor. The corridor crosses Nellis Air Force Base northeast of Las Vegas and the Nellis Air Force Range near Indian Springs. Detailed information on current and future uses of the Nellis Air Force Range is available in DIRS 103472-USAF (1999, all).

DOE uses about 32 percent of the lands associated with the Valley Modified Corridor. The corridor enters the Nevada Test Site near Mercury, traveling northwest to the Yucca Mountain site. Detailed information on current and future uses of the Nevada Test Site is available in DIRS 101811-DOE (1996, all).

The Fish and Wildlife Service manages about 3 percent of the lands associated with the Valley Modified Corridor as part of the Desert National Wildlife Refuge, which was established in 1936 for the protection and preservation of desert bighorn sheep. Portions of this refuge overlap the Nellis Air Force Range and are controlled jointly by the Air Force and the Fish and Wildlife Service. Use and public access to the joint-use area of the Desert National Wildlife Range and Nellis Air Force Range are restricted by a memorandum of understanding (DIRS 103472-USAF 1999, Appendix C). The Valley Modified corridor passes potential Wilderness Study Areas under consideration by Congress. The Quail Springs Wilderness Study Area, and the Nellis Air Force Range A, B, and C Wilderness Study Areas, located on Bureau of Land Management lands, were inventoried under the 1976 Federal Land Policy and Management Act in support of the 1964 Wilderness Act. Wilderness Study Areas cannot be altered unless they have been released from the program. At this time, there has been no action to release these areas.

The Valley Modified Corridor begins along the Union Pacific rail line in the Apex/Las Vegas area of Clark County, Nevada (Chapter 2, Figure 2-26). The corridor has two possible starting locations and two possible variations, until they merge north of the City of Las Vegas in the Apex area. Clark County is proposing an industrial park on lands transferred from the Bureau of Land Management that would encompass the primary corridor origination location. The Valley Connection starting segment begins in a Bureau corridor near private property in the vicinity of the City of North Las Vegas and travels along the Union Pacific rail line toward Apex until it turns west. The alternate segment crosses three powerline rights-of-way before turning to the west.

After the corridor turns west from either starting location, there are again two options--the corridor itself and the Sheep Mountain Option slightly north of the corridor. Both the corridor and the alternate cross Bureau of Land Management lands and then enter the Nellis Small Arms Range. After leaving the Small Arms Range, they cross the Nellis Air Force Range Wilderness Study Areas A, B, and C and then pass through the Desert National Wildlife Range and the Quail Springs Wilderness Study Area. Both cross several gravel and two-track roads, some of which enter the Desert National Wildlife Range to the north. The corridor and alternate merge before the corridor crosses the Wildlife Range and the Quail Springs Wilderness Study Area a second time. A powerline follows U.S. 95 from its intersection with State Route 157 to Mercury, where it enters the Nevada Test Site.

After the corridor and alternate join, the corridor continues to the northwest through the Las Vegas Valley, passing northeast of U.S. 95 and just to the north of Floyd Lamb State Park and the Las Vegas Paiute Reservation. It crosses several roads and two-track roads that lead into the Desert National Wildlife Range. Continuing to the northwest and running just north of U.S. 95, the corridor crosses an area close to the Desert National Wildlife Range, Desert View Natural Environmental Area, and Nellis Air Force Range.

The corridor then splits east of Indian Springs, with both segments continuing west and crossing from Clark County into Nye County east of Mercury. The northern segment (the corridor) bypasses Indian Springs and Cactus Springs, running to the north across the Desert National Wildlife Range and Bureau of Land Management lands until it merges with the southern segment just south of Mercury. The corridor crosses existing roads and tracks in the area south of Mercury, in the vicinity of Desert Rock.

The Indian Hills Alternate passes south of U.S. 95 across Bureau of Land Management lands until it crosses back to the north of U.S. 95 and joins the corridor south of Mercury. After the routes join, the corridor enters DOE property just southwest of Mercury and continues south of Skull Mountain to Yucca Mountain.

3.2.2.1.2 *Air Quality and Climate*

This section contains information on the existing air quality in areas through which the candidate rail corridors pass. It also provides background on the general climate in those areas.

Air Quality. The Caliente, Carlin, Caliente-Chalk Mountain, and Jean Corridors pass through rural parts of Nevada that are either unclassifiable or in attainment for criteria pollutants (DIRS 148123-EPA 1999, all; DIRS 149905-EPA 1999, all; DIRS 149906-EPA 1999, all; DIRS 149907-EPA 1999, all). There are no State air-quality monitoring stations in these corridors (DIRS 103404-Bureau of Air Quality 1999, pp. A1-1 through A1-9).

The Valley Modified Corridor crosses central Clark County at the north end of the Las Vegas Valley and continues in a northwest direction toward the Nevada Test Site. The air quality in the part of the corridor that passes through the Las Vegas Valley and extends part of the way to Indian Springs is in nonattainment for particulate matter with a diameter of less than 10 micrometers (PM_{10}). Clark County adopted a revised implementation plan in 2001 for demonstrating PM_{10} attainment (DIRS 155557-Clark County 2001, Executive Summary) that includes a request to the Environmental Protection Agency to extend the year for attainment demonstration of the 24-hour standard from 2001 to 2006. The plan includes proposals to reduce emissions of particulate matter from a variety of sources. A decision has not been made on the county's request for an extension to the attainment period. The Environmental Protection Agency has acknowledged the request, but has not yet completed its formal review of the revised implementation plan (DIRS 156896-Davis 2001, all).

In addition, the Las Vegas Valley air basin is in nonattainment for the 3-hour carbon monoxide standard, largely the result of vehicular emissions. Clark County adopted a State Implementation Plan for carbon monoxide to achieve the attainment criteria by December 2000 (DIRS 156706-Clark County 2000, all). The Plan outlines a methodology to maintain acceptable carbon monoxide concentrations through transportation planning and control measures. The Environmental Protection Agency has deemed the motor vehicle carbon monoxide estimates indicated in the Plan *adequate* (65 *FR* 71313; November 30, 2000). In 2000, monitoring results indicated that the Plan criteria has been met (DIRS 157158-EPA 2000, all); however, the area is still officially classified as in nonattainment.

Climate. There are two general climate descriptions for the five rail corridors: one for the three corridors that approach the Yucca Mountain site from the north and one for the two corridors that approach the site from the south or southeast. The Caliente, Carlin, and Caliente-Chalk Mountain Corridors approach from the north and cross a number of mountain ranges and valleys with elevations well above 1,500 meters (4,900 feet). Although much of Nevada is arid, in central Nye County the annual precipitation exceeds 20 centimeters (8 inches), and the annual snowfall exceeds 25 centimeters (10 inches); annual precipitation exceeds 40 centimeters (16 inches) in some mountainous areas, and snowfall exceeds 100 centimeters (40 inches) (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52). Occasional brief periods of intense rainfall at rates exceeding 5 centimeters

(2 inches) an hour can occur in the summer. Each of the three corridors approaching Yucca Mountain from the north pass through central Nye County, and DOE believes that the climate described is a reasonable average for conditions along these corridors.

The Jean and Valley Modified Corridors approach the Yucca Mountain site from the south where precipitation is generally between 10 and 20 centimeters (4 and 8 inches) per year and snowfall is rare. Occasional brief periods of intense rainfall at rates exceeding 5 centimeters (2 inches) an hour can occur in the summer (DIRS 106182-Houghton, Sakamoto, and Gifford 1975, pp. 45, 49, and 52).

3.2.2.1.3 *Hydrology*

This EIS discusses hydrologic conditions in terms of surface water and groundwater.

3.2.2.1.3.1 Surface Water. Researchers studied the alternative rail corridors for their proximity to sensitive environmental resources, including surface waters and riparian lands (DIRS 104593-CRWMS M&O 1999, Appendixes E, F, G, H, and I). The goal in planning the corridors was to avoid springs and riparian lands by 400 meters (1,300 feet) if possible. Table 3-37 summarizes potential surface-water-related resources along the candidate corridors. It lists resources within the 400-meter corridor or within a 1-kilometer (0.6-mile) region of influence along the corridor. Table 3-38 presents similar information for the variation segments. The last column of Table 3-37 identifies water resources that DOE would avoid by using a specified variation rather than the corresponding segment along the rail corridor. Water resources along the variation segment that would be "substituted" can be linked from Table 3-38. If the same water resource would be in proximity to both the corridor and variation segment, it is marked as "Avoided" in Table 3-37, but appears again in Table 3-38 for the variation.

Potential hydrologic hazards along the rail corridors include flash floods and debris flow. All corridors have potential flash flooding concerns. DOE would design and build a rail line that would be able to withstand a 100-year flood event safely.

Appendix L of this environmental impact statement is a floodplain/wetland assessment for the proposed repository action, including the Nevada transportation routes. This appendix includes the results of efforts to identify flood zones along the potential rail corridors and their associated alternate segments through the use of Flood Insurance Rate Maps published by the Federal Emergency Management Agency. The flood zone maps do not provide complete coverage for any of the rail corridors primarily because there are none for the large areas of the Nevada Test Site and the Nellis Air Force Range. In some areas the maps do, however, provide a good indication of 100-year flood zones that might exist in the rail corridors. Consistent with the distribution of surface-water resources listed in Table 3-37, the floodplain information in Appendix L (see Table L-4) indicates the greatest number of different flood zones would occur along the Caliente and Carlin Corridors.

3.2.2.1.3.2 Groundwater. Groundwater basins that the candidate rail corridors cross represent part of the potentially affected environment. As described for groundwater in the immediate region of Yucca Mountain (Section 3.1.4.2.1), the State of Nevada has been divided into groundwater basins and sub-basins. The sub-basins are called hydrographic areas. A map of these areas (DIRS 101486-Bauer et al. 1996, p. 543) was overlain with a drawing of the proposed rail corridors to produce a reasonable approximation of the areas that would be crossed by each corridor. Table 3-39 lists results of this effort for the rail corridors. Table 3-40 presents similar information for the different segments associated with the corridor variations. The tables also list estimates of the perennial yield for each hydrographic area crossed and if the area is a State Designated Groundwater Basin [a hydrographic area in which the permitted water rights approach or exceed the estimated perennial yield and the water resources are depleted or require additional administration, including a State declaration of preferred uses (municipal

Table 3-37. Surface-water-related resources along candidate rail corridors[a] (page 1 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation (Yes or No)[c]
Caliente			
Eccles Siding to Meadow Valley Wash	Within	Riparian area/stream – corridor crosses and is adjacent to stream and riparian area in Meadow Valley Wash	Y-1, 2
Meadow Valley to Sand Spring Valley	1.0	Spring – Bennett Spring, 3.2 kilometers southeast of Bennett Pass	N
	0.05 - 2.6	Springs – group of five springs (Deadman, Coal, Black Rock, Hamilton, and one unnamed) east of White River	N
	Within	Riparian/river – corridor parallels (and crosses) the White River for about 10 kilometers. August 1997 survey found river to be mostly underground with ephemeral washes above ground.	N
	0.8	Spring – McCutchen Spring, north of Worthington Mountains	N
Sand Spring Valley to Mud Lake	0.02	Spring – Black Spring, south of Warm Springs	N
Mud Lake to Yucca Mountain	Within - 2.5	Springs – numerous springs and seeps along Amargosa River in Oasis Valley	Y-8
	Within - 0.3	Riparian area/stream – designated area east of Oasis Valley, flowing into Amargosa River, also riparian area, with persistent water and extensive wet meadows near springs and seeps	Y-8
	0.3 - 1.3	Springs – group of 13 unnamed springs in Oasis Valley north of Beatty	Y-8
Carlin			
Beowawe to Austin	0.5	Spring – Tub Spring, northeast of Red Mountain	Y-11
	0.8	Spring – Red Mountain Spring, east of Red Mountain	Y-11
	0.9	Spring – Summit Spring, west of corridor and south of Red Mountain	N
	0.4	Spring – Dry Canyon Spring, west of Hot Springs Point	N
	0.8	Spring – unnamed spring on eastern slope of Toiyabe Range, southwest of Hot Springs Point	N
	1.0	Riparian area – intermittent riparian area associated with Rosebush Creek, in western Grass Valley, north of Mount Callaghan	Y-12
	Within	Riparian/creek – corridor crosses Skull Creek, portions of which have been designated riparian areas	Y-12
	Within	Riparian/creek – corridor crosses intermittent Ox Corral Creek; portions designated as riparian habitat. An August 1997 survey found creek dry with no riparian vegetation present	Y-12
	0.1	Spring – Rye Patch Spring, at north entrance of Rye Patch Canyon, west of Bates Mountain	N
	Within	Riparian area – corridor crosses and parallels riparian area in Rye Patch Canyon	Y-13
	0.7	Spring – Bullrush Spring, east of Rye Patch Canyon	N
Austin to Mud Lake	0.8	Springs – group of 35 unnamed springs, about 25 kilometers north of Round Mountain on east side of Big Smoky Valley	Y-14
	0.6	Riparian area – marsh area formed from group of 35 springs	Y-14
	0.6	Spring – Mustang Spring, south of Seyler Reservoir	Y-14
	0.3	Riparian/reservoir – Seyler Reservoir (seasonal), west of Manhattan	Y-14

Table 3-37. Surface-water-related resources along candidate rail corridors[a] (page 2 of 2).

Rail corridor	Distance from corridor (kilometers)[b]	Feature	Avoided by variation (Yes or No)[c]
Carlin (continued)			
Mud Lake to Yucca Mountain		See Caliente corridor	
Caliente-Chalk Mountain			
Eccles Siding to Meadow Valley		See Caliente corridor	
Meadow Valley to Sand Spring Valley		See Caliente corridor	
Sand Spring Valley to Yucca Mountain	1.0	Spring – Reitman's Seep, in eastern Yucca Flat, east of BJ Wye	Y-15, 16
	0.8	Spring – Can Spring, on north side of Skull Mountain on Nevada Test Site	Y-15
Jean		None identified	
Valley Modified		None identified	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).
b. To convert kilometers to miles, multiply by 0.62137.
c. Some water resources would be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation from Table 3-38 that avoids the specific resource. Table 3-38 identifies the variation by number and shows the water resources associated with the corridor segment unique to that variation. The same water resource might be in proximity to both the rail corridor and variation segment. In such cases, the resource is marked "Avoided" for the rail corridor here, but appears on Table 3-38 for the variation.

and industrial, domestic supply, agriculture, etc.)] (DIRS 103406-NDWP 1992, p. 18). These are the areas where additional water demand would be most likely to produce an adverse effect on local groundwater resources. Table 3-39 indicates that none of the corridors would completely avoid Designated Groundwater Basins. However, the Caliente-Chalk Mountain Corridor would cross only two Designated Basins, one at Panaca Valley near the start of the corridor and one at Penoyer Valley where the Caliente and Caliente-Chalk Mountain Corridors split.

The last column of Table 3-39 identifies hydrographic areas that DOE would avoid or cross differently if a corridor variation (also identified in the table) were to be used. In most cases, the variation listed in Table 3-40 would have little or no effect on the hydrographic areas crossed. The Crestline Option, Caliente Option, White River Alternate, Goldfield Alternate, and Stateline Pass Option would involve changing, dropping, or adding a single hydrographic area to those that the rail corridor would cross. The Monitor Valley Option is the only other variation that would make a difference and would result in changing two and adding one to the list of hydrographic areas that the Carlin Corridor would cross.

There are a number of published estimates of perennial yield for many of the hydrographic areas in Nevada, and they often differ from one another by large amounts. This is the reason for listing a range of perennial yield values in Table 3-11 for the hydrographic areas in the Yucca Mountain region. For simplicity, the perennial yield values listed in Table 3-39 generally come from a single source (DIRS 103406-NDWP 1992, Regions 4, 10, 13, and 14) and, therefore, do not show a range of values for each area. The hydrographic areas in the Yucca Mountain region (that is, areas 225 through 230) are the exception to perennial yield values from the single source. The perennial yield values for these areas are from DIRS 147766-Thiel (1999, pp. 6 to 12), which compiles estimates from several sources. The table lists the lowest values in that document.

The perennial yield value shown for Area 227A is the lowest estimated value presented in DIRS 147766-Thiel (1999, p. 8) and is further divided into 300 acre-feet (370,000 cubic meters) for the eastern third of the area and 580 acre-feet (720,000 cubic meters) for the western two-thirds.

Table 3-38. Surface-water-related resources along unique segments of corridor variations.[a,b]

		Water resource features	
Variation	Applicable corridor(s)[c]	Distance from corridor (kilometers)[d]	Feature
1. Crestline Option	CL/CM	0.3	Spring - Miller Spring south of SR[e] 319 and southeast of Panaca; important water source for game
		1.0	Spring - Miser Spring south of SR 319 and southeast of Panaca
		Within	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Panaca
2. Caliente Option	CL/CM	Within	Riparian area/stream - variation crosses Meadow Valley Wash stream and riparian area south of Caliente
		0.6	Spring - unnamed spring in Caliente
		Within	Spring - unnamed spring in Meadow Valley north of Caliente
		0.5	Springs - two unnamed springs in Meadow Valley north of Caliente
3. White River Alternate	CL/CM		None identified - parallels White River further than rail corridor, but not within 1 kilometer
4. Garden Valley Alternate	CL/CM		None identified
5. Mud Lake Alternate	CL/CR		None identified
6. Goldfield Alternate	CL/CR	0.6	Spring - Tognoni Springs northeast of Goldfield
		0.4	Spring - unnamed spring south of Mud Lake and east of U.S. 95
7. Bonnie Claire Alternate	CL/CR		None identified
8. Oasis Valley Alternate	CL/CR	0.5 - 3.0	Springs - numerous springs and seeps along Amargosa River in Oasis Valley
		Within - 0.3	Riparian area/stream - designated area east of Oasis Valley, flowing into Amargosa River, also a riparian area, with persistent water and extensive wet meadows near springs and seeps
		0.8 - 1.8	Springs - group of 13 unnamed springs in Oasis Valley north of Beatty
9. Beatty Wash Alternate	CL/CR		None identified
10. Crescent Valley Alternate	CR		None identified
11. Wood Spring Canyon Alternate	CR		None identified
12. Steiner Creek Alternate	CR	Within	Riparian area - variation crosses designated riparian area in Water Canyon northeast of Bates Mountain
		Within	Riparian/creek - variation crosses Steiner Creek, a designated riparian area. An August 1997 survey found creek dry and lacking riparian vegetation
13. Rye Patch Alternate	CR	0.1	Riparian area - variation parallels riparian area in Rye Patch Canyon
14. Monitor Valley Option	CR	0.7	Spring - unnamed spring east of variation and east of Toquima Range
		0.2	Riparian area - designated riparian area west of variation, northwest of Belmont. An August 1997 survey found area dry and lacking riparian vegetation.
15. Topopah Option	CM	0.6	Spring - Whiterock Spring north of variation, south of Burnt Mountain
15a. Area 4 Alternate	CM		None identified - avoids Whiterock Spring of the Tonopah Option
15b. Mine Mountain Alternate	CM		None identified - main portion of option still passes Whiterock Spring
16. Mercury Highway Option	CM		None identified
17. Pahrump Valley Alternate	J		None identified
18. Stateline Pass Option	J		None identified
19. Valley Connector	VM		None identified
20. Sheep Mountain Alternate	VM		None identified
21. Indian Hills Alternate	VM		None identified

a. Source: DIRS 104593-CRWMS M&O (1999, Appendixes E, F, G, H, and I).

b. Rail corridors are listed in Table 3-37. Water resources identified in that table that can be avoided by a variation are identified with a number designation that is consistent with the numbering in this table.

c. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.

d. To convert kilometers to miles, multiply by 0.62137.

e. SR = State Route.

Table 3-39. Hydrographic areas (groundwater basins) crossed by candidate rail corridors.

Rail corridor	Hydrographic area[a] No.	Hydrographic area[a] Name	Perennial yield (acre-feet)[b,c,d]	Designated Groundwater Basin[e,f]	Avoided by variation (Yes or No)[g]
Caliente					
Eccles Siding to Sand Spring Valley	204	Clover Valley	1,000	No	Y-1, 2
	203	Panaca Valley	9,000	Yes	Y-1, 2
	181	Dry Lake Valley	2,500	No	N
	208	Pahroc Valley	21,000	No	Y-3
	171	Coal Valley	6,000	No	Y-3
	172	Garden Valley	6,000	No	N
Sand Spring Valley to Mud Lake	170	Penoyer Valley (Sand Spring Valley)	4,000	Yes	N
	173A	Railroad Valley, southern part	2,800	No	N
	156	Hot Creek	5,500	No	N
	149	Stone Cabin Valley	2,000	Yes	N
	141	Ralston Valley	6,000	Yes	Y-6
Mud Lake to Yucca Mountain	145	Stonewall Flat	100	No	Y-6
	144	Lida Valley	350	No	N
	146	Sarcobatus Flat	3,000	Yes	N
	228	Oasis Valley	1,000	Yes	N
	229	Crater Flat	220	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Carlin	54	Crescent Valley	16,000	Yes	N
Beowawe to Austin	138	Grass Valley	13,000	No	N
	137B	Big Smoky Valley, northern part	65,000	Yes	Y-14
Austin to Mud Lake – Via Big Valley	137A	Big Smoky Valley and Tonopah Flat	6,000	Yes	Y-14
	142	Alkali Spring Valley	3,000	No	Y-14
	145 to 227A	See Caliente Corridor			
Mud Lake to Yucca Mountain					
Caliente-Chalk Mountain	204 to 170	See Caliente Corridor			
Eccles Siding to Sand Spring Valley	158A	Emigrant Valley and Groom Lake Valley	2,800	No	N
Sand Spring Valley to Yucca Mountain	159	Yucca Flat	350	No	N
	160	Frenchman Flat	16,000	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Jean	165	Jean Lake Valley	50	Yes	Y-18
Jean to Yucca Mountain	164A	Ivanpah Valley, northern part	700	Yes	Y-18
	163	Mesquite Valley (Sandy Valley)	2,200	Yes	Y-18
	162	Pahrump Valley	12,000	Yes	N
	230	Amargosa Desert	24,000	Yes	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N
Valley Modified	212	Las Vegas Valley	25,000	Yes	N
Dike Siding (north of Las Vegas) to Yucca Mountain	211	Three Lakes Valley, southern part	5,000	Yes	N
	161	Indian Springs Valley	500	Yes	N
	225	Mercury Valley	250	No	N
	226	Rock Valley	30	No	N
	227A	Fortymile Canyon and Jackass Flats	880[h]	No	N

a. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with corridor map overlay).

b. Source: DIRS 103406-NDWP (1992, Regions 4, 10, 13, and 14), except hydrographic areas 225 through 230 for which the source is DIRS 147766-Thiel (1999, pp. 6 to 12). The Nevada Division of Water Planning identifies a perennial yield of only 24,000 acre-feet (30 million cubic meters) for the combined area of hydrographic areas 225 through 230.

c. Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir.

d. To convert acre-feet to cubic meters, multiply by 1,233.49.

e. Source: DIRS 148165-NDWP (1999, Regions 4, 10, 13, and 14).

f. "Yes" indicates the State of Nevada considers the area a Designated Groundwater Basin where permitted water rights approach or exceed the estimated perennial yield and the water resources are being depleted or require additional administration, including a State declaration of preferred uses (municipal and industrial, domestic supply, agriculture, etc.). Designated Groundwater Basins are also referred to as Administered Groundwater Basins.

g. Some variations would involve crossing different hydrographic areas than those listed here for the rail corridor. In such cases, the portion of the rail corridor that corresponds to the unique variation segment is identified with a "Y" (yes) and a number representing the variation(s) from Table 3-40. Hydrographic areas in which the unique variation segment begins or ends appear both here, with a "Y," and in Table 3-40 with the applicable variation.

h. The perennial yield value shown for Area 227A is the lowest estimated value presented in DIRS 147766-Thiel (1999, p. 8) and is further broken down into 370,000 cubic meters (300 acre-feet) for the eastern third of the area and 720,000 cubic meters (580 acre-feet) for the western two-thirds.

Table 3-40. Hydrographic areas crossed by unique segments of corridor variations.

	Variation	Applicable corridor(s)[a]	Note[b]	Hydrographic area crossed[c] No.	Name	Perennial yield (acre-feet)[d,e]	Designated Groundwater Basin[d]
1.	Crestline Option	CL/CM		197	Escalante Desert	1,000	No
				203	Panaca Valley	9,000	Yes
2.	Caliente Option	CL/CM		203	Panaca Valley	9,000	Yes
3.	White River Alternate	CL/CM		208	Pahroc Valley	21,000	No
				207	White River Valley	37,000	No
				171	Coal Valley	6,000	No
4.	Garden Valley Alternate	CL/CM	(1)	171	Coal Valley	6,000	No
				172	Garden Valley	6,000	No
5.	Mud Lake Alternate	CL/CR	(1)	141	Ralston Valley	6,000	Yes
6.	Goldfield Alternate	CL/CR		141	Ralston Valley	6,000	Yes
				142	Alkali Spring Valley	3,000	No
				145	Stonewall Flat	100	No
7.	Bonnie Claire Alternate	CL/CR	(1)	144	Lida Valley	350	No
				146	Sarcobatus Flat	3,000	Yes
8.	Oasis Valley Alternate	CL/CR	(1)	228	Oasis Valley	1,000	Yes
9.	Beatty Wash Alternate	CL/CR	(2)	228	Oasis Valley	1,000	Yes
				229	Crater Flat	220	No
10.	Crescent Valley Alternate	CR	(1)	54	Crescent Valley	16,000	Yes
11.	Wood Spring Canyon Alternate	CR	(1)	54	Crescent Valley	16,000	Yes
12.	Steiner Creek Alternate	CR	(1)	138	Grass Valley	13,000	No
13.	Rye Patch Alternate	CR	(1)	137B	Big Smoky Valley, north	65,000	Yes
14.	Monitor Valley Option	CR		137B	Big Smoky Valley, north	65,000	Yes
				140A	Monitor Valley, north	8,000	No
				140B	Monitor Valley, south	10,000	No
				141	Ralston Valley	6,000	Yes
15.	Topopah Option	CM	(2)	159	Yucca Flat	350	No
				160	Frenchman Flat	16,000	No
				227A	Fortymile Canyon, Jackass Flats	880	No
16.	Mercury Highway Option	CM	(2)	159	Yucca Flat	350	No
				160	Frenchman Flat	16,000	No
17.	Pahrump Valley Alternate	J	(1)	162	Pahrump Valley	12,000	Yes
18.	Stateline Pass Option	J		164A	Ivanpah Valley, north	700	Yes
				163	Mesquite Valley (Sandy Valley)	2,200	Yes
19.	Valley Connector	VM	(2)	212	Las Vegas Valley	25,000	Yes
20.	Sheep Mountain Alternate	VM	(1)	212	Las Vegas Valley	25,000	Yes
21.	Indian Hills Alternate	VM	(2)	211	Three Lakes Valley, south	5,000	Yes
				161	Indian Springs Valley	500	Yes

a. Rail corridor abbreviations used in the table are defined as follows: CL = Caliente; CM = Caliente-Chalk Mountain; CR = Carlin; J = Jean; VM = Valley Modified.

b. Notes:
1. The corresponding portion of the rail corridor passes over the same hydrographic area(s) for approximately the same distance(s).
2. The corresponding portion of the rail corridor passes over the same hydrographic area(s), but for slightly different distance(s).

c. Source: DIRS 101486-Bauer et al. (1996, pp. 542 and 543 with corridor map overlay).

d. Source: DIRS 103406-NDWP (1992, pp. 21 to 25), except hydrographic areas 225 through 230 for which the source is DIRS 147766-Thiel (1999, pp. 6 to 12).

e. To convert acre-feet to cubic meters, multiply by 1,233.49.

3.2.2.1.4 *Biological Resources and Soils*

3.2.2.1.4.1 Biological Resources. The following sections describe biological resources along each of the candidate rail corridors. These environments include habitat types and springs and riparian areas located in a 400-meter (1,300-foot)-wide corridor along each route. Springs and riparian areas are important because they provide habitat for large numbers of plants, animals, and insects. Unless otherwise noted, this information is from the *Environmental Baseline File for Biological Resources* (DIRS 104593-CRWMS M&O 1999, all).

Caliente. From the beginning of the corridor at Caliente to Mud Lake, the Caliente Corridor crosses Meadow, Dry Lake, Coal, Garden, Sand Spring, Railroad, Reveille, Stone Cabin, and Ralston Valleys. From Mud Lake, the corridor crosses Stonewall and Sarcobatus flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. The valleys and flats along the corridor range in elevation from 900 to 1,800 meters (3,000 to 5,900 feet). The corridor also crosses through passes or foothills of several mountain ranges including the Highland, Seaman, Golden Gate, Worthington, and Kawich mountain ranges at elevations ranging from 1,600 to 1,900 meters (5,200 to 6,200 feet). The Caliente Corridor is in the southern Great Basin from its beginning at Caliente to near Beatty Wash. The land cover types along this portion of the corridor include salt desert scrub (60 percent) and sagebrush (33 percent). South of Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-22). Table 3-41 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Caliente Corridor. Unless specifically identified otherwise, the text does not describe resources along the corridor variations (that is, options and alternates).

The only resident threatened or endangered species in the Caliente Corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in this area is low in relation to other areas in the range of the species in Nevada (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O’Farrell 1998, pp. 407 to 411). Southwestern willow flycatchers *(Empidonax traillii extimus)*, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The Railroad Valley springfish (*Crenichthys nevadae*), which is Federally threatened and State protected (Nevada Administrative Code 503.067) occurs in Warm Springs about 3 kilometers (1.9 miles) north of the corridor in Hot Creek Valley (DIRS 103261-FWS 1996, all).

Three other species classified as sensitive by the Bureau of Land Management occur in the corridor. Unnamed subspecies of the Meadow Valley Wash speckled dace (*Rhinichthys osculus* ssp.) and Meadow Valley Wash desert sucker (*Catostomus clarki* ssp. 2) have been found in Meadow Valley Wash north of Caliente. In the Beatty area, the Nevada sanddune beardtongue (*Penstemon arenarius*) has been found on sandy soils 10 kilometers (6 miles) north of Springdale. Though not listed in the table, a number of bats classified as sensitive by the BLM also may occur along the corridor and the southern end of the corridor is in the range of the chuckwalla (*Sauromalus obesis*).

The Caliente Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 101523-BLM 1994, Maps 9 through 13). The corridor crosses bighorn sheep (*Ovis canadensis*) habitat west of Goldfield near Stonewall Mountain. It also crosses mule deer use areas in or near the Chief/Delamar, Worthington, Quin Canyon, Reveille, and Kawich mountain ranges. The corridor crosses pronghorn antelope (*Antilocapra americana*) habitat in the Railroad/Reveille, Sandspring, Stone Cabin, and Ralston Valleys; Ralston Range; and north of Goldfield. Parts of Meadow Valley Wash north of Caliente are classified as waterfowl and quail habitat, and the corridor crosses another area classified as quail habitat at the north end of the Chief Range.

At least four springs or groups of springs and three streams or riparian areas are within 0.4 kilometer (0.25 mile) of the corridor (DIRS 104593-CRWMS M&O 1999, Appendix E). These might be wetlands or other waters of the United States, as defined in the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Black Spring is near the corridor at the north end of the Kawich Range and an unnamed spring is near the corridor at the north end of the North Pahroc Range. A series of springs is in the corridor near the Amargosa River in Oasis Valley. The corridor crosses the Meadow Valley Wash south of Panaca. The corridor also crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock

Table 3-41. Biological resources in or near the Caliente Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Caliente rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Railroad Valley springfish		1
Sensitive species or habitat		
Amargosa toad		5
Eastwood milkvetch		1
Fringed myotis		1
Funeral Mountain milkvetch		1
Hawk nesting area		1
Meadow Valley Wash desert sucker	1	
Meadow Valley Wash speckled dace	1	
Needle Mountain milkvetch		3
Nevada Sanddune beardtongue	1	1
Oasis Valley speckled dace		2
Oasis Valley springsnail		1
Game habitat		
Bighorn–year round	1	2
Mule deer–winter use	2	
Mule deer–summer use		1
Mule deer–year round	3	1
Pronghorn–year round	6	
Quail–crucial	1	
Quail-year round	1	
Waterfowl–crucial	1	
Springs or groups of springs	4[e]	24[f]
Riparian areas	3	1
Herd Management Units	8	
Caliente Option[g]		
Sensitive species		
Welch’s catseye		1
Springs or groups of springs	1	4[f]
Crestline Option[g]		
Sensitive species		
Needle Mountain milkvetch		3
Game habitat		
Bighorn sheep–crucial		1
Mule deer–crucial		1
White River Alternate[g]		
Sensitive species		
Pygmy rabbit		1
Welch’s catseye		1
Garden Valley Alternate[g]		
Sensitive species		
Welch’s catseye		1
Goldfield Alternate[g]		
Springs or groups of springs		2[f]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix E, pp. E-1 to E-12).
b. There are no biological resources unique to the Mud Lake, Bonnie Claire, Oasis Valley, or Beatty Wash Alternates.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
g. Only resources unique to this alignment variation are listed.

waterholes. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management (DIRS 101523-BLM 1994, Maps 14 and 15). The corridor also crosses a number of *ephemeral* streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. Four of the variations (Crestline Option, Caliente Option, Goldfield Alternate, and Oasis Valley Alternate) along the Caliente Corridor would affect the number of, or distance to, associated water resources. Using the Crestline Option, Caliente Option, or Goldfield Alternate would add one spring within 0.4 kilometer (0.25 mile) of the corridor. The Oasis Alternate is close to the same water resources as the corresponding portion of the rail corridor, but it would be farther away from two groups of springs identified near the Amargosa River.

The Caliente Corridor also crosses eight Bureau of Land Management-designated wild horse or wild horse and burro herd management areas (DIRS 101504-BLM 1979, pp. 2-26 through 2-35; DIRS 101523-BLM 1994, Maps 18 and 19). From the beginning of the corridor to Sand Spring Valley, the corridor passes through herd management areas in the Cedar and Chief Ranges. From Sand Spring Valley to Mud Lake, the corridor crosses the Saulsbury, Reveille, and Stone Cabin herd management areas, and from Mud Lake to Yucca Mountain the route crosses the Goldfield, Stonewall, and Bullfrog herd management areas.

Carlin. The Carlin Corridor crosses Crescent and Grass Valleys, then passes through Big Smoky Valley to Mud Lake. From Mud Lake, the corridor crosses Stonewall and Sarcobatus Flats, the upper portion of the Amargosa River, the lower portion of Beatty Wash, and Crater and Jackass Flats. Elevations along the route range from 900 to 2,200 meters (3,000 to 7,200 feet).

The Carlin Corridor is in the Great Basin from its start in Beowawe to near Beatty Wash. Land cover types along this portion of the corridor are dominated by salt desert scrub (57 percent), sagebrush (28 percent), and greasewood (7 percent). At Beatty Wash, the corridor crosses into the Mojave Desert. Predominant land cover types from Beatty Wash to Yucca Mountain include creosote-bursage (59 percent), Mojave mixed scrub (22 percent), and salt desert scrub (19 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-24). Table 3-42 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Carlin Corridor (without options or alternates) unless specifically identified otherwise.

The only resident threatened or endangered species in the Carlin Corridor is the desert tortoise, which occurs only along the southern end of the corridor from about Beatty Wash to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance in the region is low (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411).

Three other species classified as sensitive by the Bureau of Land Management or as protected by Nevada occur along the Carlin Corridor. A ferruginous hawk (*Buteo regalis*) (also classified as protected by Nevada) nesting area is east of Mount Callaghan. The San Antonio pocket gopher (*Thomomys umbrinus curtatus*) has been found in Big Smoky Valley northwest of the San Antonio Mountains. The Nevada sand dune beardtongue has been found in sandy soils 10 kilometers (6 miles) north of Springdale. A number of bats classified as sensitive by the Bureau of Land Management might occur along the corridor, and the southern end of the corridor is in the range of the chuckwalla.

The Carlin Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 103077-BLM 1983, Map 3-1; DIRS 101523-BLM 1994, Maps 9 to 13; DIRS 104593-CRWMS M&O 1999, p. 3-25). The corridor crosses an area designated as sage grouse (*Centrocercus urophasianus*) habitat in western Grass Valley and another at the southeast end of Rye Patch Canyon. The corridor enters pronghorn antelope habitat north of U.S. Highway 50 near Rye Patch Canyon, along most of Big Smoky Valley, and from Mud Lake to Stonewall Mountain. The corridor crosses mule deer habitat on the west side of Grass Valley and bighorn sheep habitat east of Goldfield**.**

Three springs, five riparian areas, and one reservoir are within 0.4 kilometer (0.25 mile) of the Carlin corridor (DIRS 104593-CRWMS M&O 1999, Appendix F). These areas might be wetlands or other waters of the United States, as defined by the Clean Water Act, although no formal wetlands delineation has been conducted along the corridor. Rye Patch Spring is on the edge of the corridor at the south end of the Simpson Park Mountains. A series of springs is in the corridor near the Amargosa River in Oasis Valley. Seyler Reservoir is less than 0.3 kilometer (0.2 mile) from the corridor in the south end of Big Smoky Valley. Three of the riparian areas (Skull and Ox Corral Creeks, and Rye Patch Canyon) are along the section of the route between Beowawe and Austin at the south end of Grass Valley. Ox Corral Creek, at the south end of Grass Valley, is ephemeral and has little or no riparian vegetation where the route crosses it. The corridor crosses the Amargosa River in the north end of the Oasis Valley, in an area designated as a riparian area by the Bureau of Land Management. This corridor also crosses a number of ephemeral streams that might be classified as waters of the United States under Section 404 of the Clean Water Act. Five of the variations (Oasis Valley Alternate, Steiner Creek Alternate, Rye Patch Alternate, Monitor Valley Option, and Goldfield Alternate) would affect the number of, or distance to Carlin Corridor water resources. Changes associated with the Oasis Valley and Goldfield Alternates were covered above in the Caliente Corridor discussion. The Rye Patch Alternate would involve no changes to water resources identified in, or within 0.4 kilometer of the rail corridor, but would parallel the riparian area in Rye Patch Canyon rather than cross it. The Steiner Creek Alternate would avoid two riparian areas, but another two would be within this variation. The Monitor Valley Option would represent a major change in the corridor, but with respect to water resources within 0.4 kilometer, it would avoid only Seyler Reservoir and would add a designated riparian area northwest of Belmont in its stead.

Table 3-42. Biological resources in or near the Carlin Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Carlin rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Sensitive species		
Amargosa toad		5
Big Smoky Valley speckled dace		1
Crescent Dune aegialian scarab		1
Eastwood milkvetch		1
Ferruginous hawk (nesting area)	1	2
Fringed myotis		1
Funeral Mountain milkvetch		1
Nevada Sanddune beardtongue	1	1
Oasis Valley speckled dace		2
Oasis Valley springsnail		1
Pygmy rabbit		1
San Antonio pocket gopher	1	
Game habitat		
Bighorn–year round	1	2
Mule deer–spring	1	3
Mule deer–summer		3
Mule deer–winter		2
Mule deer–year round		3
Pronghorn–summer	1	
Pronghorn–year round	2	
Sage grouse nesting area		1
Sage grouse strutting ground	2	3
Waterfowl		
Springs or groups of springs	3[e]	60[f]
Riparian areas	5	7
Herd Management Units	6	
Wood Spring Canyon Alternate[g]		
Game habitat		
Mule deer–summer		1
Steiner Creek Alternate[g]		
Springs or groups of springs		3[f]
Riparian areas	2	
Rye Patch Alternate[g]		
Springs or groups of springs		1[f]
Monitor Valley Option[g]		
Sensitive species		
Eastwood milkvetch		1
Pygmy rabbit		1
Speckled dace		1
Game habitat		
Elk	1	
Mule deer–spring	1	
Mule deer–winter		3
Pronghorn–winter	1	
Pronghorn–year round	1	
Sage grouse	2	5
Sage grouse–nesting	1	2
Sage grouse–strutting	1	1
Springs or groups of springs		19[f]
Riparian areas	1	5
Herd Management Units	2	
Goldfield Alternate[g]		
Springs or groups of springs	1	1[e]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix F, pp. F-1 to F-16).
b. There are no biological resources unique to the Crescent Valley, Mud Lake, Bonnie Claire, Oasis Valley, or Beatty Wash Alternates.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
g. Only resources unique to this alignment variation are listed.

The corridor crosses two wild horse or wild horse and burro herd management areas between Beowawe and Austin (Mount Callaghan and Bald Mountain), one in Big Smoky Valley (Hickison) and three between Mud Lake and Yucca Mountain (Goldfield, Stonewall, and Bullfrog) (DIRS 103077-BLM 1983, Map 2-4; DIRS 101523-BLM 1994, Maps 18 and 19).

Caliente-Chalk Mountain. The Caliente-Chalk Mountain Corridor begins near Caliente and is identical to the Caliente Corridor from Caliente to Sand Spring Valley, crossing Meadow, Dry Lake, Coal, and Garden Valleys at elevations ranging from 1,400 to 1,600 meters (4,600 to 5,200 feet). This portion of the corridor also crosses through passes or foothills of the Highland, Seaman, Golden Gate, and Worthington mountain ranges at elevations of 1,500 to 1,800 meters (4,900 to 5,900 feet). After splitting from the Caliente Corridor, the Caliente-Chalk Mountain Corridor proceeds south through Sand Spring and Emigrant Valleys, over Groom Pass, and through Yucca and Jackass Flats to Yucca Mountain. The elevation along this portion of the route ranges from approximately 1,100 to 1,700 meters (3,600 to 5,600 feet).

Predominant land cover types between Caliente and Sand Spring Valley include sagebrush (50 percent) and salt desert scrub (47 percent). The vegetation along the route from Sand Spring Valley to Yucca Flat is typical of the southern portion of the Great Basin. From Yucca Flat to Yucca Mountain, the corridor passes through a zone of transition between the Mojave and Great Basin deserts. The predominant land cover types from Sand Spring Valley to the Yucca Mountain site are blackbrush (50 percent), salt desert scrub (31 percent), and sagebrush (9 percent). Table 3-43 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Caliente-Chalk Mountain Corridor (without variations) unless specifically identified otherwise.

Table 3-43. Biological resources in or near the Caliente-Chalk Mountain Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]	Resource	Occurrences[a] In corridor	Occurrences[a] Within 5 km[d]
Caliente-Chalk Mountain rail corridor			Springs or groups of springs	1[e]	14[f]
Threatened or endangered species			Riparian areas	2	
Desert tortoise			Herd Management Units	2	
Sensitive species			*Mercury Highway Option*[g]		
Beatley's scorpionweed		17	Sensitive species		
Funeral Mountain milkvetch		1	Hilend's bedstraw		2
Hawk nesting area		1	Largeflower suncup		2
Largeflower suncup	1	18	Ripley's springparsley	2	6
Long-legged myotis		1	Springs or groups of springs		2[f]
Meadow Valley Wash desert sucker	1		*Topopah Option*[g]		
Meadow Valley Wash speckled dace	1		Sensitive species		
Needle Mountain milkvetch		3	Clokey's egg milkvetch		2
Oasis Valley springsnail		1	Hilend's bedstraw		3
Ripley's springparsley	1	1	Paiute beardtongue		4
Game habitat			Ripley's springparsley		2
Mule deer–winter	1		Springs or groups of springs		3[f]
Mule deer–summer		1	*Mine Mountain Alternate*[g]		
Mule deer–year round	2		Sensitive species		
Pronghorn–year round	1		Funeral Mountain milkvetch		4
Quail–crucial	1		Largeflower suncup		2
Quail–year round	1		Paiute beardtongue		2
Waterfowl–crucial	1		Springs or groups of springs		1[f]

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix G, pp. G-1 to G-9).
b. There are no biological resources unique to the Area 4 Alternate. Biological resources for the Crestline and Caliente Options can be found in Table 3-41 for the Caliente Corridor.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs inside or within 400 meters (1,300 feet) of the corridor.
f. Only resources unique to this alignment variation are listed.

The only resident threatened or endangered species in the Caliente-Chalk Mountain Corridor is the desert tortoise, which occurs on the Nevada Test Site south of Yucca Flat. This area is not critical habitat for desert tortoises (50 CFR 17.95) and their abundance is low (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). Southwestern willow flycatchers, an endangered species, have been observed in dense stands of riparian vegetation in Lincoln County, but there is no suitable habitat for this species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

Four species classified as sensitive by the Bureau of Land Management have been found in the corridor. Unnamed subspecies of the Meadow Valley Wash speckled dace and Meadow Valley Wash desert sucker have been found in Meadow Valley Wash. Ripley's springparsley (*Cymopterus ripleyi* var. *saniculoides*) has been reported between Sand Spring Valley and Yucca Mountain in Yucca Flat. The largeflower suncup (*Camissonia megalantha*) has been found in the corridor at three locations in Yucca Flat. Bats classified as sensitive by the Bureau of Land Management also may occur near the corridor. Chuckwalla may occur in suitable habitat on the Nevada Test Site.

The Caliente-Chalk Mountain Corridor crosses several areas designated as game habitat by the Bureau of Land Management (DIRS 101504-BLM 1979, pp. 2-26 through 2-35; DIRS 101523-BLM 1994, Maps 9, 10, and 11). The corridor crosses mule deer use areas in or near the Chief and Delamar ranges, Worthington and Quinn Canyon ranges and north of Groom Pass. The corridor crosses pronghorn habitat in Sand Spring and Emigrant Valleys. Parts of Meadow Valley north of Caliente are classified as waterfowl and quail habitat and the corridor crosses another area classified as quail habitat at the north end of the Chief Range.

At least one spring or group of springs and two streams occur within 0.4 kilometer (0.25 mile) of the corridor. These areas might be classified as wetlands or other waters of the United States (DIRS 104593-CRWMS M&O 1999, p. 3-27), as defined in the Clean Water Act, although no formal wetlands delineation has been conducted. An unnamed spring is near the corridor at the north end of the North Pahroc Range. The corridor crosses Meadow Valley Wash south of Panaca. The corridor crosses the White River between U.S. 93 and Sand Spring Valley and parallels the river for approximately 10 kilometers (6 miles). An August 1997 survey of that portion of the river found it was mostly dry with some standing water in stock waterholes. This corridor also crosses a number of ephemeral streams or washes that might be classified as waters of the United States. Two of the variations (Crestline Option and Caliente Option) would affect the number of or distance to, water resources within a 0.4 kilometer (0.25 mile) of the Caliente-Chalk Mountain Corridor. Changes in the list of nearby water resources for both of these options were covered above in the Caliente Corridor discussion.

The Caliente-Chalk Mountain Corridor passes through two wild horse or wild horse and burro herd management areas (DIRS 101504-BLM 1979, pp. 2-42 and 2-43; DIRS 101523-BLM 1994, Maps 18 and 19) in the Cedar Mountains south of Panaca and in the Chief Range west of Panaca.

Jean. The Jean Corridor starts in Ivanpah Valley north of Jean and proceeds west of Wilson Pass to the Pahrump Valley. The corridor continues to the Yucca Mountain site through Pahrump Valley and across the Amargosa Desert and Jackass Flats. This corridor is in the Mojave Desert, with elevations ranging from about 850 to 1,500 meters (2,800 to 4,900 feet).

The predominant land cover types in the corridor are creosote-bursage (59 percent), Mojave mixed scrub (21 percent), and blackbrush (18 percent) (DIRS 104593-CRWMS M&O 1999, p. 3-28). Table 3-44 lists the biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Jean Corridor (without alternates) unless specifically identified otherwise.

The only resident threatened or endangered species in the Jean Corridor is the desert tortoise. The entire corridor is in the range of this species (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Along most of the corridor, especially the western portions from Pahrump to Yucca Mountain, the abundance of desert tortoises is low (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 101914-Rautenstrauch and O’Farrell 1998, pp. 407 to 411). However, some areas crossed by the corridor in Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have a higher abundance of tortoises (DIRS 101521-BLM 1992, Map 3-13). The corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95).

One location of each of two subspecies of the pinto beardtongue (*Penstemon bicolor bicolor* and *P.b. roseus),* which is classified as sensitive by the Bureau of Land Management, is in the first 5 kilometers (3 miles) of the corridor near Jean. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters (*Heloderma suspectus cinctum*), and a number of bat species classified as sensitive probably occur there in suitable habitat.

The Jean Corridor crosses several areas the Bureau of Land Management designates as game habitat (DIRS 103079-BLM 1998, Maps 3-7, 3-8, and 3-9). The corridor crosses chukar habitat north of Goodsprings, and quail habitat northwest of Wilson Pass, east of Pahrump, and northwest of Johnnie. The corridor crosses mule deer winter habitat around Wilson Pass and north of Pahrump. The southern edge of bighorn sheep winter range is crossed in the southern Bird Spring Mountains and crucial bighorn habitat is crossed around Wilson Pass. The corridor also crosses a bighorn sheep migration route between the Bird Springs and Spring Mountains and a potential migration corridor from winter range in the Devils Hole Hills to historic but currently unoccupied habitat at the west end of the Spring Mountains.

Table 3-44. Biological resources in or near the Jean Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Jean rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Sensitive species		
Allen's big-eared bat		1
Death Valley beardtongue		3
Desert bearpoppy		3
Fringed myotis		1
Gila monster		1
Long-legged myotis		1
Oasis Valley springsnail		1
Pinto beardtongue	2	18
Redheaded sphecid wasp		1
Sheep fleabane		1
Spring Mountain milkvetch		2
Townsend's big-eared bat		1
White-margined beardtongue		5
Wolly sage		1
Yuma myotis		1
Game habitat		
Bighorn sheep–crucial	1	1
Bighorn sheep–migration corridor	2	
Bighorn sheep–winter	1	7
Chukar–crucial	1	
Mule deer–summer crucial		2
Mule deer–winter	2	2
Quail–crucial	3	4
Springs or groups of springs		11[e]
Herd Management Units	3	
Stateline Pass Option[f]		
Sensitive species		
White-margined beardtongue		1
Pinto beardtongue		1
Desert bearpoppy		7
Rusby's globemallow		1
Pahrump Valley buckwheat		3
Game habitat		
Bighorn sheep–winter	1	
Quail–crucial		2

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix H, pp. H-1 to H-9).
b. There are no biological resources unique to the North Pahrump Valley Alternate.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
f. Only resources unique to this alignment variation are listed.

There are no springs, perennial streams, or riparian areas within 0.4 kilometer (0.25 mile) of this corridor or its variations. The corridor crosses a number of ephemeral washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

There are three wild horse and burro herd management areas in the corridor (DIRS 103079-BLM 1998, Map 2-1). The Red Rock herd management area is southeast of the Spring Mountains and the Wheeler Pass and Johnnie herd management areas are west of the Spring Mountains.

Valley Modified. The Valley Modified Corridor begins in the northeastern corner of the Las Vegas Valley, crosses the northern edge of the valley south of the Las Vegas Range, and continues northwest toward Indian Springs. The route continues across the southern portion of Three Lakes and Indian Springs Valleys to the Nevada Test Site and passes through Mercury Valley, Rock Valley, and Jackass Flats to the Yucca Mountain site. The corridor ranges in elevation from approximately 700 to 1,100 meters (2,300 to 3,600 feet).

This route is in the Mojave Desert and the predominant land cover types are creosote-bursage (79 percent) and Mojave mixed scrub (16 percent; DIRS 104593-CRWMS M&O 1999, p. 3-29). Table 3-45 lists biological resources, including sensitive species, identified in or near the corridor. The following paragraphs describe biological resources in the Valley Modified Corridor (without alternatives) unless specifically identified otherwise.

The only resident threatened or endangered species in the Valley Modified Corridor is the desert tortoise. The entire corridor is in the range of this species (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). In general, the abundance of tortoises along this corridor through Las Vegas Valley, Indian Springs Valley, and the Nevada Test Site is low (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). This corridor does not cross areas classified as critical habitat for desert tortoises (50 CFR 17.95). The razorback sucker (*Xyrauchen texanus*), classified as threatened under the

Table 3-45. Biological resources in or near the Valley Modified Corridor.[a,b]

Resource	Occurrences[c] In corridor	Occurrences[c] Within 5 km[d]
Valley Modified rail corridor		
Threatened or endangered species		
Desert tortoise	1	
Pahrump poolfish		2
Razorback sucker		1
Sensitive species		
Beatley's scorpionweed		1
California bearpoppy		17
Death Valley beardtongue		2
Desert bearpoppy		11
Largeflower suncup		3
Mojave milkvetch		1
Parish's scorpionweed	3	6
Pinto beardtongue		2
Ripley's springparsley	1	1
Townsend's big-eared bat		1
White-margined beardtongue		1
Game habitat		
Bighorn sheep–crucial		1
Bighorn sheep–winter		3
Mule deer–winter		1
Quail–crucial		2
Springs or groups of springs		3[e]
Indian Hills Alternate[f]		
Sensitive species		
Desert bearpoppy		1
Mojave milkvetch		4
Herd Management Units	1	

a. Source: DIRS 104593-CRWMS M&O (1999, Appendix I, pp. I-1 to I-6).
b. There are no biological resources unique to the Sheep Mountain Alternate or Valley Connector.
c. An occurrence represents a distinct population or habitat. The desert tortoise, for example, might occur within 5 kilometers (3 miles) of the corridor as well as within the corridor but, because it is in the same general habitat, it is listed only once on the table.
d. 5 kilometers = 3 miles.
e. Springs 400 to 5,000 meters (1,300 to 16,000 feet) from the corridor.
f. Only resources unique to this alignment variation are listed.

Endangered Species Act and as protected under Nevada Administrative Code, have been introduced into ponds at Floyd Lamb State Park, 4.2 kilometers (2.6 miles) south of the corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29). Refuge populations of the Pahrump poolfish (*Empetrichthys latos latos*), classified as endangered under the Endangered Species Act and Nevada Administrative Code, have been introduced into ponds in Floyd Lamb State Park and into the outflow of Corn Creek Springs, 4.5 kilometers (2.8 miles) northeast of the corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29).

Two other species classified as sensitive by the Bureau of Land Management occur in the corridor. Three populations of Parish's scorpionweed (*Phacelia parishii*) and a population of Ripley's springparsley have been reported on the Nevada Test Site in Rock Valley. No other Bureau of Land Management sensitive species have been documented in the corridor, although chuckwalla, gila monsters, and a number of bat species probably occur there in suitable habitat.

There are no herd management areas, Areas of Critical Environmental Concern, or designated game habitat in the Valley Modified Corridor (DIRS 104593-CRWMS M&O 1999, p. 3-29; DIRS 103079-BLM 1998, Maps 3-7, 3-8, and 3-9). No springs or riparian areas occur within 0.4 kilometer (0.25 mile) of this rail corridor or its variations. This corridor crosses a number of ephemeral streams or washes that might be classified as waters of the United States under Section 404 of the Clean Water Act.

3.2.2.1.4.2 Soils. Soil surveys have been performed and documented throughout much of the United States, including portions of Nevada, by the U.S. Department of Agriculture. Further, the Department of Agriculture has undertaken several efforts to compile this soil survey data into computerized databases for use by government agencies and the general public. One of these databases, the State Soil Geographic database, was developed by generalizing more detailed soil survey data; its purpose is to support planning on the State and multicounty level (DIRS 154246-USDA 1994, pp. 1 and 2). The Yucca Mountain

Project has queried the database for information on soils along the rail corridors. Though the database presents generalized, or higher level information, it still contains massive amounts of data, much more than can be presented in this EIS. However, DOE selected several soil characteristics with potential for environmental impact implications for presentation here to indicate the types of soil along the corridors. One of the database elements selected was soil areas designated as prime farmland. Prime farmlands are defined as lands that have the best combination of physical and chemical characteristics needed to economically produce sustained high-yield agricultural crops [7 CFR 657.5(a)]. Based on the query of the State Soil Geographic database, there are no soils classified as prime farmlands in the rail corridors, including the option and alternate segments (DIRS 155600-Sorensen 2001, p. 2).

DOE also queried the database for other codes representing soil attributes that could be of concern from an environmental perspective and that would need to be considered during the design and construction of a new branch rail line. The query was made by overlaying the rail corridor locations on the soil units in the database and the result was the identification, by corridor segment, of whether the identified attribute might be present in the area in or around the segment. The selected soil attributes in this query are termed “shrink swell,” “erodes easily,” “unstable fill,” and “blowing soil.” Each of these attributes not only represents potential environmental and construction concerns, but is associated with physical characteristics of soil. The following paragraphs describe these attributes.

The *shrink swell* attribute is a gauge of how much the volume of a soil changes when it is wet compared to when it is dry. In the State Soil Geographic database, any soil that swells less than 3 percent when wet is considered to have “low” limitations with respect to its use in construction; 3 to 6 percent is considered to present “moderate” limitations and greater than 6 percent has “high” limitations [DIRS 155602-USDA 2001, Part 620.05(a)(2) and Table 620-2]. Querying the database for the shrink swell code identifies (but does not distinguish) soils with moderate or high limitations. The purpose of these limitations is not to indicate that construction cannot or should not be performed in such soils, but rather that the design and construction plans need to account for that soil characteristic. A soil’s potential for volume change with loss or gain of moisture varies with the amount and type of clay minerals it contains. In general, more clay in the soil indicates a greater volume change.

The *erodes easily* attribute is a measure of the susceptibility of bare soil to be detached and moved by water. It is based on a factor (designated as “K”) used in the commonly employed Universal Soil Loss Equation [DIRS 155602-USDA 2001, Part 620.04 and 620.06(f)(9)]. Measurements on standardized plots are used to determine experimentally values for K, which range from 0.02 to 0.64. Other factors in the equation being equal, a higher K value indicates more susceptibility to erosion by water. The main properties affecting this attribute are soil texture, organic material structure, and permeability. In general, clay soils have low K values because they are resistant to detachment, and sandy soils have low values because they have high infiltration rates (reduced runoff) and particles that erode are not easily transported. Silt loam soils have moderate to high K values. Silt soils have the highest values because they readily form crusts that promote runoff and the particles are easily detached and transported (DIRS 155601-USDA 2001, all). Querying the database for the *erodes easily* code identifies soils with K values greater than 0.35. These are soils with fair to poor erosion characteristics when disturbed and that probably contain relatively high amounts of loams and silts.

The *unstable fill* attribute is a measure of a soil’s tendency to move when it is wet or loaded, or both. Stable soils are generally not subject to mass movement under these conditions, and moderately stable soils can involve mass movement when a moderate disturbance provides the initiating action. In unstable soils, slight disturbances can result in mass movement when soil is wet or loaded [DIRS 155602-USDA 2001, Part 620.12(a)(1) and Table 620-37]. Soils identified in the database with the *unstable fill* code are those likely to be moderately stable or unstable when used as fill.

The *blowing soil* attribute is based on groupings used during soil surveys to classify the susceptibility of soil to wind erosion. This classification method uses eight groupings. Soils assigned to group 1 are the most susceptible to wind erosion and those assigned to group 8 are the least susceptible. Descriptions of soils in the groupings range from sands to coarse fragments not susceptible to wind erosion (DIRS 155602-USDA 2001, Part 618.72 and Exhibit 618-16). Querying the database for the blowing soil code identifies soils with wind erodibility groups of 1 or 2 [DIRS 155602-USDA 2001, Part 620.06(f)(9) and Table 620-11]. The definitions of these two groups are as follows:

- Group 1 - Coarse sands, sands, fine sands, and very fine sands
- Group 2 - Loamy coarse sands, loamy sands, loamy fine sands, loamy very fine sands, ash material and sapric (fine, decomposed, organic muck) soil material

The blowing soil attribute identifies areas where fine textured, sandy materials probably predominate and where uncontrolled soil disturbance could result in increased wind erosion.

The following paragraphs discuss the results of the State Soil Geographic database query for the four identified soil attributes by rail corridor. In general terms, the corridors that approach Yucca Mountain from the north (that is, the Caliente, Carlin, and Caliente-Chalk Mountain Corridors) encounter relatively high percentages of soils with *shrink swell*, *erodes easily*, and *blowing soil* characteristics. The corridors that approach Yucca Mountain from the south (that is, the Jean and Valley Modified Corridors) encounter relatively high percentages of soils with only two of those characteristics (that is, *shrink swell* and *blowing soil*). None of the corridors would have high percentages of *unstable fill*, though such soil is present in about 10 percent of the Jean Corridor. The corridor-specific soil information presented in the following paragraphs does not represent detailed soil survey data, but does provide insight into the soil characteristics and potential environmental aspects that would have to be considered during the engineering and design of a branch rail line. Should a decision be made to select one of the rail corridors for transportation of materials to Yucca Mountain, DOE would perform soil surveys of the selected corridor to collect detailed information on the environmental and engineering characteristics of the soils that would be encountered.

Caliente Corridor. Table 3-46 lists the percentage of the Caliente Corridor that crosses soils with the four attributes described in this section. The percentage is the portion of the corridor in which the identified soil attribute could present a concern or limitation for the construction of a rail line. The *shrink swell*, *erodes easily*, and *blowing soils* attributes are prevalent along this corridor. Soils with shrink swell and erodes easily attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, pp. 15 and 16). The *blowing soil* attribute is associated with soils scattered heavily throughout the State (DIRS 155600-Sorensen 2001, p. 18). The corridor crosses no soil areas identified with the *unstable fill* attribute. As indicated in the table, the use of any of the alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 3 percent.

Table 3-46. Percentage of the Caliente Corridor with selected soil attributes.[a]

	Percentage of corridor with identified soil attribute			
Description	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Caliente Corridor	61	69	0	81
Change with any other alternate/option	± 3	± 3	± 0	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Carlin Corridor. Table 3-47 lists the percentage of the Carlin Corridor that crosses soils with the four attributes described in this section. The *shrink swell, erodes easily*, and *blowing soils* attributes are prevalent along this corridor. Soils with *shrink swell* and *erodes easily* attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, p. 15 and 16). The *blowing soil* attribute is associated with soils scattered throughout the State (DIRS 155600-Sorensen 2001, p. 18). The Carlin Corridor would cross no soil areas identified with the *unstable fill* attribute. If the Monitor Valley option was used, the soil attribute percentages would change little with the exception of the *shrink swell* attribute, which would increase by

Table 3-47. Percentage of the Carlin Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Carlin Corridor	56	69	0	88
With Monitor Valley Option	76	69	0	84
Change with any other alternate/option	± 2	± 3	± 0	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

about 20 percent. As indicated in the table, the use of any of the other alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 3 percent.

Caliente-Chalk Mountain. Table 3-48 presents the percentage of the Caliente-Chalk Mountain rail corridor that would cross soils with the four attributes described in this section. As can be seen in the table, the *shrink swell, erodes easily,* and *blowing soils* attributes are prevalent along this rail corridor as they are for the other two corridors that would approach the site from the north. Soils with *shrink swell* and *erodes easily* attributes are common throughout most of the northern two-thirds of Nevada with more scattered presence in the southern third (DIRS 155600-Sorensen 2001, pp. 15 and 16). The *blowing soil* attribute is associated with soils scattered heavily throughout the state (DIRS 155600-Sorensen 2001, p. 18). The Caliente-Chalk Mountain rail corridor would cross no soil areas identified with the *unstable fill* attribute. As shown in the table, use of any one of the other alternate or option segments would change the portion of the corridor with any of the identified soil attributes by no more than 4 percent.

Table 3-48. Percentage of the Caliente-Chalk Mountain rail corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Caliente-Chalk Mountain rail corridor	52	75	0	86
Change with any single alternate/option	± 4	± 3	± 0	± 2

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Jean Corridor. Table 3-49 lists the percentage of the Jean Corridor that would cross soils with the four attributes described in this section. The *shrink swell* and *blowing soils* attributes are prevalent along this corridor even though these soils occur only in scattered locations in southern Nevada (DIRS 155600-Sorensen 2001, pp. 16 and 18). A small amount of this corridor passes through soil areas with *erodes easily* and *unstable fill* attributes. As indicated in the table, if DOE used the Stateline Pass Alternate, the percentage of the corridor crossing soils with *erodes easily* and *blowing soil* attributes would increase about 10 percent for either attribute. Use of the Pahrump Alternate would result in little or no change in the corridor's soil attributes.

Table 3-49. Percentage of the Jean Corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Jean Corridor	89	11	10	77
With Pahrump Valley Alternate	89	11	10	78
With the Stateline Pass Alternate	92	19	11	91

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

Valley Modified Corridor. Table 3-50 lists the percentage of the Valley Modified Corridor that crosses soils with the four attributes described in this section. The *shrink swell* and *blowing soils* attributes are prevalent along this corridor, even though these soils occur only in scattered locations in southern Nevada (DIRS 155600-Sorensen 2001, pp. 16 and 18). This corridor would not pass through any significant amount of soil area with *erodes easily* and *unstable fill* attributes. As indicated in the table, if DOE used

Table 3-50. Percentage of the Valley Modified rail corridor with selected soil attributes.[a]

Description	Percentage of corridor with identified soil attribute			
	Shrink swell	Erodes easily	Unstable fill	Blowing soil
Valley Modified Corridor	76	0	0	76
With the Indian Hills Alternate	92	0	0	92
Change with any other alternate	± 1	± 0.2	± 0.2	± 1

a. Source: DIRS 155600-Sorensen (2001, pp. 4 to 14).

the Indian Hills Alternate, the percentage of the corridor crossing soils with *shrink swell* and *blowing soil* attributes would increase about 16 percent for either attribute. Use of either of the other two alternates (Valley Connector or Sheep Mountain) would result in little change in the corridor's soil attributes.

3.2.2.1.5 *Cultural Resources*

The baseline environmental conditions presented in this section focus on the archaeological and historic resources associated with the candidate rail corridors. This section also discusses Native American interests in relation to two of the corridors. Unless otherwise noted, this information is from the *Environmental Baseline File for Archaeological Resources* (DIRS 104997-CRWMS M&O 1999, all). In addition, information from the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all) and *Additional Baseline Cultural Resources Data for the Nevada Transportation Scenario* (DIRS 155826-Nickens and Hartwell 2001, all) were used.

Archaeological and Historic Resources. Based on a records search at the Desert Research Institute in Las Vegas and Reno, the Harry Reid Center at the University of Nevada, Las Vegas, and the Bureau of Land Management Battle Mountain and Elko Offices, archaeological surveys have been conducted in less than 1 percent of the total areas for the Caliente, Jean, and Valley Modified Corridors, less than 3 percent of the total area for the Carlin Corridor, and less than 5 percent of the total area for the Caliente-Chalk Mountain Corridor. The record searches examined each candidate rail corridor, including the variations. Although it is possible to identify areas in a corridor that are most likely to contain cultural resources based on such factors as general land forms and proximity to water, these predictions are highly uncertain prior to corridor selection and the completion of intensive field studies and, therefore, are not included in this EIS.

Initially, archaeological site file searches were completed for larger rail corridors, ranging between 1.6 and 8 kilometers (1 and 5 miles) in total width. More than 2,300 archaeological and historic sites were documented for these wider corridors. The wider corridors used in the initial records searches included all corridor variations. As project plans become more detailed, it was possible to reduce the potential corridor width to a 0.2-kilometer (0.1-mile)-wide buffer zone on either side of the centerline. Records indicate that a number of archaeological sites have been identified along the reduced corridors and that some of these sites are recorded as potentially eligible for nomination to the *National Register of Historic Places*. Table 3-51 summarizes this information. The table also lists potentially eligible sites by type. For conservatism, this group includes sites not yet evaluated for eligibility. The sites recorded but not included in the potentially eligible group represent sites that had no recommendations about eligibility to the National Register.

DOE is implementing the stipulations and forms of a Programmatic Agreement (DIRS 104558-DOE 1988, all) with the Advisory Council on Historic Preservation to address DOE's responsibilities under Sections 106 and 110 of the National Historical Preservation Act and the Council's implementing regulations. Although not a formal signatory to the Agreement, the Nevada State Historic Preservation Officer has the right at any time, upon request, to participate in monitoring DOE compliance with the Programmatic Agreement. In addition, DOE provides annual reports to the Advisory Council on Historic

Table 3-51. Number of previously recorded archaeological sites along candidate rail corridors including variations [based on corridor width of 0.4 kilometer (0.25 mile)].

Category[a]	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Potentially eligible for nomination					
Temporary camps	--[b]	--	3	--	--
Extractive localities	--	--	3	--	--
Processing localities	--	--	--	--	--
Localities	--	1	16	--	--
Caches	--	--	--	--	--
Stations	--	--	--	--	--
Historic sites	--	--	3	--	--
Unknown type	7	20	3	--	7
Total potentially eligible	*7*	*21*	*28*	*0*	*7*
Not evaluated	29	26	6	2	4
Recorded sites (approximate total)	*97*	*110*	*100*	*6*	*19*

a. Section 3.1.6 contains the definitions of site types for potentially eligible for nomination sites (temporary camps, extractive localities, etc.).
b. -- = none identified.

Preservation and the Nevada State Historic Preservation Officer describing the activities conducted by DOE each year to implement the stipulations of the Programmatic Agreement. This report includes a description of DOE coordinations and consultations with Federal and State agencies and Native American tribes concerning historic and culturally significant properties at Yucca Mountain.

DOE will continue to seek input from the Nevada State Historic Preservation Officer and the Advisory Council on Historic Preservation, and will interact appropriately to meet the reporting and other stipulations of the existing Programmatic Agreement. Because the 1988 Programmatic Agreement primarily covers site characterization activities at the Yucca Mountain site, DOE would negotiate a new programmatic agreement to cover cultural resources requirements for any selected Nevada transportation corridor.

Records and literature reviews reveal the presence of numerous historic properties and districts that one or more of the candidate rail corridors could affect, depending on the route selected. A number of these are linear features that a given corridor would intersect. Table 3-52 lists the more important of these linear properties.

In addition to the linear historic properties, the candidate rail corridors are close to several other historic properties, many of which are already listed on either the *Nevada State Register of Historic Places* or the *National Register of Historic Places*, or are currently unevaluated. Table 3-53 lists the more important properties.

Other potentially important historic properties that could be within rail corridors include elements of many historic mining districts, several historic ranches (especially Crescent, Grass, Big Smoky, and Monitor Valleys), and the World War II Tonopah Army Air Field bombing range. Numerous Cold War-era resources that have been documented at the Nevada Test Site could be affected (for example, Camp Desert Rock).

Native American Interests. Through the American Indian Writers Subgroup of the Consolidated Group of Tribes and Organizations, Native Americans have noted that, while transportation issues are of extreme interest to them, at present they cannot provide specific comments on any of the Nevada transportation project alternatives (DIRS 102043-AIWS 1998, pp. 4-4 to 4-6) due to the absence of systematic ethnographic studies for any of the proposed project areas.

Table 3-52. Historic period linear cultural resource properties intersected by potential rail corridors and variations.[a]

Property	Rail corridor-variation	National Historic Trail Designation Status[b]
California Emigrant Trail (1840s)	Carlin	Designated *California National Historic Trail.* Segment is designated Low Potential.[c]
Western Pacific Railroad (1907)	Carlin	
Salt Lake to San Francisco Transcontinental Airways Route (1920-1940s) and Parran to Beowawe Cutoff (1928-1929)	Carlin	
Jedidiah Smith Exploration Route (1827)	Carlin - Monitor Valley Option	
John C. Fremont Military Reconnaissance Route (1845-1846)	Carlin - Big Smoky Valley Option	
James Simpson Federal Wagon Road Route Survey (1859)	Carlin and Monitor Valley Options	
Pony Express Trail (1861)	Carlin and Rye Patch Alternates and Monitor Valley Option	Designated *Pony Express National Trail.* Segment is designated High Potential.[c]
Pacific Telegraph Line (1861)	Carlin and Rye Patch Alternate	
Butterfield Overland Mail & Stage Route (1861)	Carlin and Rye Patch Alternate	
Lincoln Highway (1920s)	Carlin and Rye Patch Alternates and Monitor Valley Option	
Tonopah-Goldfield Railroad (1903-1947)	Carlin/Caliente	
Las Vegas and Tonopah Railroad (1905-1918)	Carlin/Caliente Valley Modified and Indian Hills and Sheep Mountain Alternates	
Jayhawker's Emigrant Trail (1849)	Caliente/Caliente-Chalk Mountain	
Old Spanish Trail (1830); later the Mormon Road (after 1850)	Jean and Stateline Pass Option	Under evaluation for designation by Congress as a National Historic Trail
Yellow Pine Mining Company railroad (1911-1934)	Jean	
Las Vegas to Bullfrog Stage Road (1904-1906)	Carlin Valley Modified - Indian Hills Alternate	
Caliente and Pioche Railroad (1907)	Caliente and Caliente and Crestline Options	

a. Source: DIRS 155826-Nickens and Hartwell (2001, pp. 15 and 20 to 25).

b. Those properties showing no status entries are neither designated by Congress as National Historic Trails nor under evaluation for such a status.

c. Trail segments are evaluated for their potential to afford a high-quality recreation experience in a portion of the route having greater than average scenic values or affording an opportunity to vicariously share the experience of the original users of the trail. Evaluations shown here apply to the trail segment intersected by the applicable rail corridor.

Table 3-53. Cultural resource properties close to proposed rail corridors and listed on State or National Registers of historic places.[a]

Property	Rail corridor	Status
Tonopah Multiple Resource Area	Carlin/Caliente	NRHP
Belmont Historic District	Carlin – Monitor Valley Option	NSRHP, NRHP
Goldfield Historic District	Carlin/Caliente and Goldfield Alternates	NRHP
Union Pacific Depot, Caliente	Caliente	NRHP
Smith (Scott) Hotel, Caliente	Caliente	NSRHP
Sedan Crater Area 10, Nevada Test Site	Caliente-Chalk Mountain	NRHP
Goodsprings Mining District	Jean	NSRHP
Tule Springs Archaeological Site	Valley Modified	NSRHP, NRHP
Corn Creek Campsite	Valley Modified	NRHP
Tule Springs Ranch District	Valley Modified	NRHP

a. Source: DIRS 155826-Nickens and Hartwell (2001, Table 6, pp. 17-19).
b. NRHP = *National Register of Historic Places*; NSRHP = *Nevada State Register of Historic Places.*

General concerns for potential transportation-related impacts raised by Native Americans include the following:

- Radioactive and hazardous waste transportation could have an adverse impact along rail or highway routes near existing or planned Native American communities, people, businesses, and resources.

- All of the proposed routes being considered pass through the traditional holy lands of the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone peoples.

- Many of these routes correspond or are adjacent to ancient pathways and complex trail systems known to and used by Native American peoples.

- The Consolidated Group of Tribes and Organizations is aware of important culturally sensitive areas, traditional use areas, sacred sites, and other important resources that fall in the proposed transportation project areas, and will present this information when appropriate in the development of the Nevada transportation system.

These general concerns apply to the proposed rail corridors discussed in this section, and the proposed heavy-haul truck route alternatives and intermodal transfer station locations discussed in Section 3.2.2.2.5.

There are three known historic period Native American cemeteries, two in Crescent Valley and one to the south in Grass Valley. One of the Crescent Valley cemeteries is still in use and is about 1.6 kilometers (1 mile) east of the corridor; the other smaller, early historic cemetery is possibly located within the corridor. The Native American cemetery in Grass Valley might also be located within the corridor. In addition, Western Shoshone families use several hot springs in Crescent Valley for ceremonies. Archaeological investigations in Grass Valley have documented the presence of several historic period Western Shoshone villages, many near ranches that employed Native Americans. For example, at the Grass Valley Ranch, which the Carlin route passes, there are six known villages, several of which might be in the Carlin corridor. Late 19th- and 20th-century Native American villages and homes found in association with Euro-American ranches could occur in many of the valleys that the rail corridors pass through. The same might be true at several mining districts that attracted Native Americans with employment opportunities.

Recent Native American field studies (DIRS 156932-AIET 2000, all) have demonstrated the importance of the Wild Horse and Willow Springs areas, which occur on Nellis Air Force Range and Bureau of Land Management lands east of the Town of Goldfield. The combined Carlin-Caliente Corridor passes to the east of the two springs; the Goldfield Alternate passes to the west. The Goldfield Alternate is the closest to either spring, being about 1.2 kilometers (0.7 mile) west of Willow Springs (DIRS 104593-CRWMS M&O 1999, Appendix E, p. E-10).

Native American communities are present near at least two of the candidate rail corridors:

- *Jean.* The Pahrump Paiute Tribe is a non-Federally recognized tribe without a land base. The tribe consists of about 100 Southern Paiute people living in the Pahrump area (see Section 3.1.6.2). Individual members of the tribe live as close as 5 kilometers (3 miles) to the Jean Corridor.

- *Valley Modified.* The Las Vegas Paiute Tribe is a Federally recognized tribe consisting of about 100 people living on two separate tribal parcels in southern Nevada. One parcel near downtown Las Vegas consists of about 73,000 square meters (18 acres) of land with 21 homes, tribal administrative offices, and various tribal businesses. This parcel is about 11 kilometers (7 miles) from the route of the Valley Modified Corridor. The other parcel is in the northwest part of the Las Vegas Valley along U.S. 95. It consists of 16 million square meters (4,000 acres) with 12 homes and various business enterprises. This parcel is about 1.6 kilometers (1 mile) from the Valley Modified Corridor.

Congress has assigned trust lands to the Timbisha Shoshone that would directly involve the Carlin and Caliente Corridors. This is the Timbisha Shoshone Tribe Homeland effort, part of which transfers 11 square kilometers (2,800 acres) of Bureau of Land Management land at Scottys Junction to the Secretary of the Interior to hold in trust for the Tribe. This area is within the Tribe's former homeland and several tribal families lived there. The Tribe plans to use this tract for single-family residences and small-scale economic development (DIRS 154121-DOI 2000, Volume I, p. 19). The Bonnie Claire Alternate of both the Carlin and Caliente Corridors passes directly through the tract transferred to the Timbisha Shoshone Tribe.

In addition, private Native American land holdings could be affected along the Carlin corridor. Western Shoshone families own ranches in Crescent Valley, and several allotments were made to Western Shoshone individuals by the U.S. Government from 1919 to 1925 under provisions of the Dawes Allotment Act of 1887. Several of these allotments were in Big Smoky Valley and Monitor Valley.

3.2.2.1.6 *Socioeconomics*

Section 3.1.7 describes the socioeconomic backgrounds of the three counties (Clark, Lincoln, and Nye) most involved in the corridors. The Carlin corridor includes other counties—Esmeralda, Eureka, and Lander—in addition to Nye County. This section contains baseline socioeconomic information for Eureka, Esmeralda, and Lander Counties.

Socioeconomic effects from the construction of a rail line would be small and, for the most part, short-term. Therefore, the socioeconomic information for Esmeralda, Eureka, and Lander Counties is less detailed than the information for the counties in the repository site region of influence in Section 3.1.7.

Population. Section 3.1.7.1 contains population data on Clark, Lincoln, and Nye Counties. This section provides population background for the other counties potentially affected by the Carlin Corridor (Esmeralda, Eureka, and Lander).

The population of Esmeralda County is 100 percent rural. The 1990 Census population for the county was about 1,300 persons. The 2000 population density of the county is somewhat less than 0.3 person per square mile. The estimated Esmeralda County population in 2000 was about 970 (DIRS 155872-Bureau of the Census 2000, County Totals).

The population of Eureka County is 100 percent rural. The 1990 Census population of the county was about 1,500. The estimated population of Eureka County in 2000 was about 1,650 (DIRS 155872-Bureau of the Census 2000, County Totals). The 2000 population density was about 0.4 person per square mile.

The population of Lander County is rural, with a small urbanized population concentrated entirely in Battle Mountain. The 1990 Census population of the county was about 6,300 persons. The estimated population of Lander County in 2000 was about 7,100 (DIRS 155872-Bureau of the Census 2000, County Totals). The county had a 2000 population density of about 1.2 persons per square mile.

Employment. Section 3.1.7.2 contains employment and economic information on Clark, Nye, and Lincoln Counties. Portions of the potential Carlin rail route pass through Esmeralda, Eureka, and Lander Counties. In 2000, Esmeralda, Eureka, and Lander Counties had average labor forces of about 470, 850, and 2,320, respectively, and average unemployment rates of 10.0, 2.6, and 7.7 percent (DIRS 155818-NDETR 2001, all). In 1997, the per capita income of Esmeralda, Eureka, and Lander Counties was about $19,200, $22,000, and $21,000, respectively (DIRS 153928-NDA 2000, all). All three of these counties are small in economic terms.

Housing. Section 3.1.7.4 contains housing data on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are all rural areas. The housing stock of Esmeralda County in 1990 was about 1,000 units, of which about 590 were occupied (DIRS 148097-Bureau of the Census 1998, Esmeralda). There were about 830 units in 2000 (DIRS 155872-Bureau of the Census 2000, all). The housing stock of Eureka County in 1990 was about 820 units, of which about 620 were occupied (DIRS 148097-Bureau of the Census 1998, Eureka). In 2000, there were about 1,000 units (DIRS 155872-Bureau of the Census 2000, Eureka). The housing stock of Lander County in 1990 was about 2,600 housing units, of which about 2,200 were occupied (DIRS 148097-Bureau of the Census 1998, Lander). In 2000, there were about 2,800 units (DIRS 155872-Bureau of the Census 2000, Lander).

Economy. Section 3.1.7.2 contains employment and economic information on Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander are very small counties in economic terms. Eureka and Esmeralda Counties derive most of their economic activity from the accommodations and food service industry. Lander County's largest industries are in the retail and wholesale sectors. Like Lincoln County, Esmeralda and Lander have lower per capita incomes than other Nevada counties and chronically high unemployment.

Public Services. Section 3.1.7.5 contains information on public services in Clark, Lincoln, and Nye Counties. Esmeralda, Eureka, and Lander Counties are rural areas. County sheriff departments serve Eureka, Esmeralda, and Lander Counties. During the 2000-2001 school term, the Eureka County school district served 305 students, the Lander County district enrolled 1,449 (847 kindergarten through grade 6 and 602 secondary students), and the Esmeralda County school district served 107 students in kindergarten through grade 8. High-school aged students from Esmeralda attended school in Tonopah (Nye County) (DIRS 155820-NDE 2001, "Nevada School Enrollment 2000-2001"). In 1998, Esmeralda had no practicing doctors or dentists, Eureka had a single practicing physician but no dentists, and Lander County had three doctors and two dentists (DIRS 153928-NDA 2000, all).

3.2.2.1.7 *Noise and Vibration*

Most of the proposed rail corridors pass through unpopulated desert with average day-night background sound levels of 22 to 38 A-weighted decibels (dBA). (A-weighted decibels are explained in Section 3.1.9.1.) However, each candidate corridor passes near small rural communities (see Chapter 6, Figures 6-15 through 6-19). Noise levels in rural communities usually range from 40 to 55 dBA. DOE used computerized mapping programs to examine proposed transportation corridors for the presence and proximity to routes that could be designated for the transfer of nuclear material to the Yucca Mountain site. The process involved the examination of computerized maps at very high detail to determine the extent of road grids in communities and major road intersections. The analysis estimated the distance from the proposed rail corridor and the community to determine if the community was in the region of influence for rail transportation.

Caliente. Most of the Caliente Corridor passes through undeveloped Bureau of Land Management land where background noise levels range from 22 to 38 dBA (Table 3-32), influenced primarily by wind. Noise levels of 40 to 55 dBA are present in the rural communities along the corridor including Beatty, Goldfield, Panaca, and Caliente (Table 3-32).

Carlin. The Carlin Corridor, from its origin at Beowawe to its terminus at Yucca Mountain, including the Monitor Valley option and other options south of Tonopah, traverses mostly unpopulated desert. The only town within 1.6 kilometers (1 mile) of the corridor is Hadley at the southern end of Big Smoky Valley (Monitor Valley option). Noise levels of 40 to 55 dBA are present in rural communities near the corridor, including Beatty, Goldfield, Tonopah, Austin, and smaller communities between Tonopah and Battle Mountain (Table 3-32). Occasional noise from military aircraft overflights occurs near the Nellis Air Force Range.

Caliente-Chalk Mountain. Almost half of the 345-kilometer (214-mile) Caliente-Chalk Mountain Corridor is on Nellis Air Force Range or Nevada Test Site land; the remainder is on Bureau on Land Management land. Noise levels of 40 to 55 dBA are present in rural communities along the corridor including Panaca and Caliente (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Jean. The Jean Corridor, with the Stateline option, passes through Bureau of Land Management land and a small section of private land. A large portion of this proposed corridor passes through unpopulated desert. Noise levels of 40 to 55 dBA are present in small communities along the corridor including Amargosa Valley, Goodsprings, Pahrump, and Jean (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Valley Modified. The Valley Modified Corridor, and its various options, begins in the northeast end of the Las Vegas Valley, travels west across Nellis Air Force Base and the southern end of the Desert National Wildlife Range, and then closely parallels U.S. 95 to the vicinity of Mercury (a government installation). Noise levels along stretches of unpopulated desert should range from 22 to 38 dBA, which are typical for a desert environment during calm and windy days (DIRS 101531-Brown-Buntin 1997, p. 7). The corridor would pass 3 kilometers (2 miles) north of Floyd R. Lamb State Park and less than 5 kilometers (3 miles) south of Corn Creek Station, which is part of the Desert National Wildlife Range managed by the Fish and Wildlife Service. Noise levels at the state park and at Corn Creek would probably be only slightly higher than those in an unpopulated desert environment. Noise levels in the northern Las Vegas Valley can be as high as 60 dBA (Table 3-32). Noise levels in Indian Springs, Cactus Springs, and Mercury probably range from 40 to 55 dBA (Table 3-32). Occasional noise from military aircraft overflights occurs near and in the Nellis Air Force Range.

Ground Vibration. Railroad construction and the operation of trains transporting materials and nuclear waste in casks have been proposed for several candidate rail corridors. These corridors have been planned to avoid human residences and communities to the extent possible. As a consequence, background levels of ground vibration lack human influence and are small; that is, most likely less than 50 VdB (velocity decibels, a measure of vibration amplitude).

3.2.2.1.8 *Aesthetics*

To assist in the management of public lands under its control, the Bureau of Land Management established land management guidelines based on the visual resources of an area. Visual resources include the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. There are four visual resource classes. Classes I and II are the more highly valued. Class III is moderately valued, and Class IV is of least value. The majority of land in the potential rail corridors is under the jurisdiction of the Bureau of Land Management. The following paragraphs contain aesthetic baseline information for each of the rail corridors. Visual resource classifications described for the rail corridors were obtained from published Bureau of Land Management documents or through conversations with Bureau of Land Management personnel. Scenic quality classifications for lands that would be crossed on the Nevada Test Site were generated by DOE using Bureau of Land Management guidelines. Section 3.1.10 contains more information on the Bureau of Land Management visual resource classes and scenic quality classes. Unless otherwise noted, this information is from the *Environmental Baseline File: Aesthetics* (DIRS 105002-CRWMS M&O 1999, all).

Caliente. Section 3.2.2.1.4 describes the environmental setting along the Caliente Corridor. The corridor passes through the Caliente, Schell, Tonopah, and Las Vegas Bureau of Land Management resource areas. The corridor crosses mostly Class IV lands, crosses Class III land near Caliente, and crosses or skirts the edges of Class II lands near Caliente and in the Seaman, Reveille and Kawich ranges, the Golden Gate Hills, and the Worthington Mountains. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Carlin. Section 3.2.2.1.4 describes the environmental setting of the Carlin corridor. The corridor passes through four Bureau of Land Management resource areas (Elko, Shoshone-Eureka, Tonopah, and Las Vegas). The route is on Class IV land from its beginning to the Nevada Test Site border. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Caliente-Chalk Mountain. Section 3.2.2.1.4 describes the environmental setting of the Caliente-Chalk Mountain Corridor. The corridor passes through the Caliente and Schell Bureau of Land Management resource areas. The route begins on Class III land east of Caliente, and crosses mostly Class IV land to the border of the Nevada Test Site (Figure 3-31). On the Nevada Test Site the corridor passes through lands with scenic quality Class B or C.

Jean. Section 3.2.2.1.4 describes the environmental setting of the Jean Corridor. The corridor crosses the Las Vegas and the Northern and Eastern Mojave Bureau of Land Management resource areas. The Wilson Pass Option of the corridor passes through Class II land in Goodsprings Valley and the Spring Mountains, but the rest of the route to the west and the Stateline Pass Option cross Class III land. Approximately 10 kilometers (6 miles) of the route crosses lands in California; that area does not have Visual Resource Management class ratings. Lands crossed on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Valley Modified. Section 3.2.2.1.4 describes the environmental setting of the Valley Modified Corridor. The corridor crosses the Las Vegas Bureau of Land Management resource area. The entire route to the boundary of the Nevada Test Site crosses Class III land. Lands on the Nevada Test Site have scenic quality ratings of Class B or C (Figure 3-31).

Section 3.2.2.1.1 contains additional information on current land use. Based on these descriptions, all of the candidate rail corridors have been affected to some extent by man. Based on a field survey by DOE, these impacts can be seen from the potential corridors and in detail from the adjacent mountains.

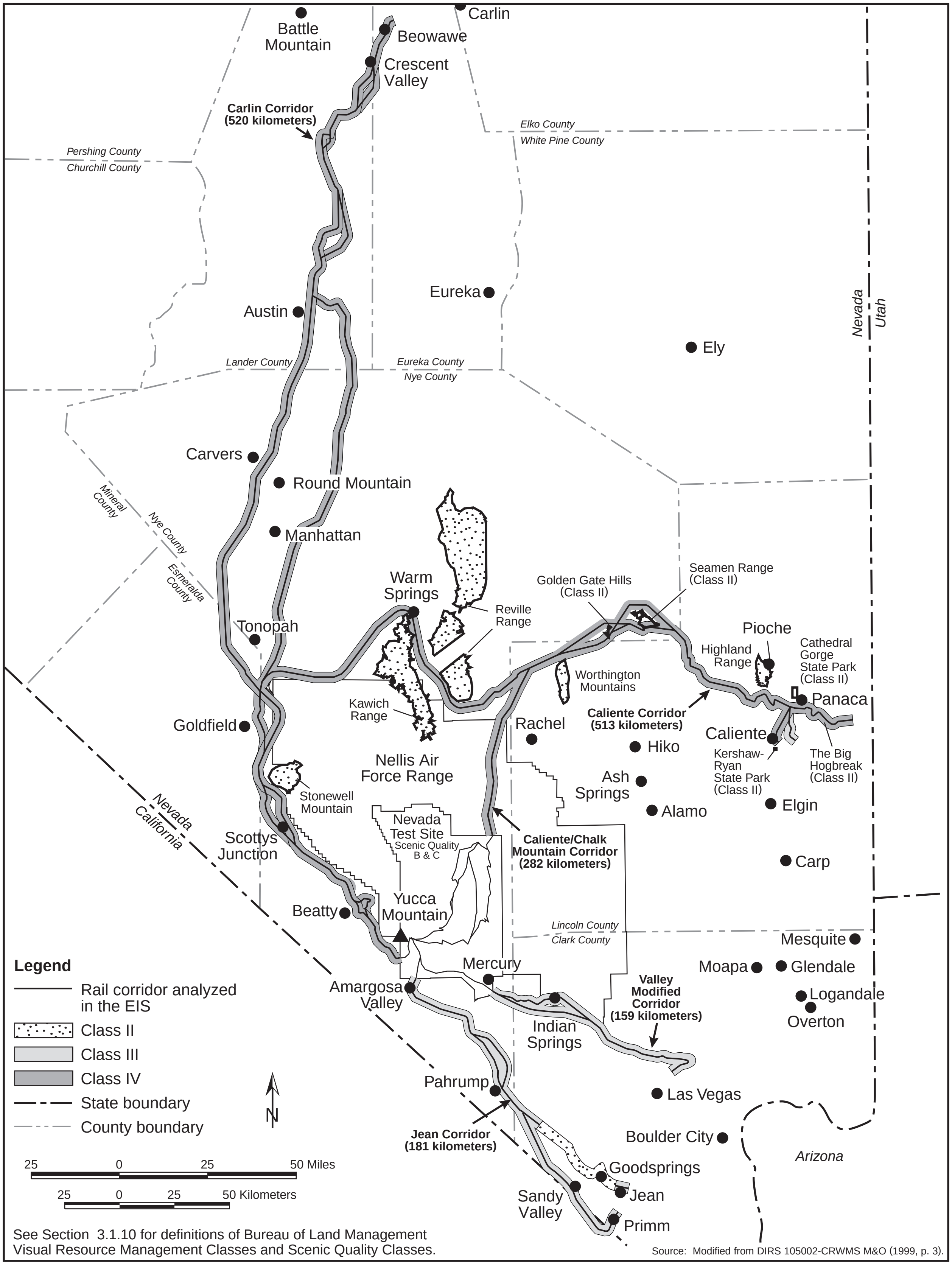


Figure 3-31. Visual Resource Management classes along the potential rail corridors.

3.2.2.1.9 *Utilities, Energy, and Materials*

All five primary rail corridors pass through typically remote Nevada countryside but are within the southern Nevada supply chain for the commodities required during construction and operation. Electric power, which would be available to a limited extent at nearby communities or other locations near power lines, probably would not be needed.

3.2.2.1.10 *Environmental Justice*

The five candidate rail corridors would not appreciably affect counties other than those through which they pass. Section 3.1.13 contains information on the minority and low-income communities in the three counties most involved in the corridors (Clark, Lincoln, and Nye) and includes Figures 3-27 and 3-28, which show locations of minority and low-income communities, respectively, in Nevada. Figures 3-29 and 3-30 provide similar information, at a higher resolution, for the Las Vegas metropolitan area in Clark County. The Carlin corridor is the only route that passes through other counties (Esmeralda, Eureka, and Lander, in addition to Nye). This section contains baseline information on minority and low-income communities in Esmeralda, Eureka, and Lander Counties, in addition to the information shown in Figures 3-27 and 3-28. Unless otherwise noted, the *Environmental Baseline File for Environmental Justice* (DIRS 105004-CRWMS M&O 1999, all) is the basis for the information in this section. DOE has updated and refined information germane to the environmental justice analysis since the Publication of the Draft EIS, including an additional and more detailed mapping of minority populations (see Appendix J, Section J.3.1.2). Although 2000 Census data concerning minority communities in Nevada were available at the Census block level in time for the Final EIS analysis, 2000 Census data on low-income communities were not. Therefore, the information on low-income communities is from the most current available source, the 1990 Census.

In 2000, the minority population (White Hispanic, Black, Asian/Pacific Islander, American Indian/ Eskimo/Aleut, and Other) of Esmeralda County was about 190, or 20 percent of the population (DIRS 156909-Bureau of the Census 2001, p. 6 of Table DP-1; Esmeralda County). In 1990, there were about 210 persons living in poverty, or 15 percent of the population. No block group in Esmeralda County exceeded the threshold for identification as a low-income community (DIRS 103134-Bureau of the Census 1992, Table P117). (Section 3.1.13 defines minority and low-income communities.)

In 2000, the minority population of Eureka County was about 250 persons, or 15 percent (DIRS 156909-Bureau of the Census 2001, p. 7 of Table DP-1; Eureka County). In 1990, there were about 160 persons living in poverty, or 10 percent of the population. No block group in Eureka County exceeded the threshold for identification as a low-income community (DIRS 103141-Bureau of the Census 1992, Table P117).

In 2000, the minority population of Lander County was about 1,400 persons, or 24 percent (DIRS 156909-Bureau of the Census 2001, p. 9 of Table DP-1; Lander County). In 1990, there were about 670 persons living in poverty, or 11 percent of the population. No block group in Lander County exceeded the threshold for identification as a low-income community (DIRS 103144-Bureau of the Census 1992, Table P117).

Some detail on the affected environment for environmental justice that was presented in the Draft EIS for rail corridors has been deleted because of a change in the nature and level of available information. Because of the differences in the level of data between the minority and low-income categories, a combined, parallel discussion is no longer appropriate. The baseline presentation of information now relies on the Section 3.1.13 figures referenced above to identify locations of minority and low-income communities in proximity to the candidate rail corridors.

D Indicates conditions in which speed and the ability to maneuver are severely restricted due to traffic congestion.

E Indicates full capacity; a disruption, no matter how minor, causes backups to form.

F Indicates breakdown of flow or stop-and-go traffic.

Each level is defined by a range of volume-to-capacity ratios. Level of service A, B, or C is considered good operating conditions in which minor or tolerable delays of service are experienced by motorists. Level of service D represents below average conditions. Level of service E corresponds to the maximum capacity of the roadway. Level of service F indicates a heavily congested or overburdened capacity. Roads outside the Las Vegas metropolitan area are generally level of service A or B; roads inside the Las Vegas metropolitan area are generally level of service E or F. Table 3-60 lists current levels of service on potential heavy-haul truck routes (excluding the planned Las Vegas Beltway).

Table 3-60. Existing levels of service along candidate routes for heavy-haul trucks.[a]

Route segment	Level of service
Caliente	
U.S. 93 to U.S. 6/U.S. 95 interchange	A
U.S. 95/U.S. 6 to Tonopah city limit	C
U.S. 95 (to Mercury, Nevada)	B
Caliente/Chalk Mountain	
Caliente to Rachel	A
Cost of route on U.S. Government Facility	N/A
Caliente/Las Vegas	
U.S. 93 (between I-15 and Caliente)	A
I-15 (to Craig interchange)	A
I-15 (in Las Vegas)	E or F[b]
U.S. 95 (in Las Vegas)	E or F[b]
U.S. 95 (Las Vegas to Mercury)	B
Sloan/Jean	
I-15 (to and in Las Vegas)	C, F[b]
U.S. 95 (in Las Vegas)	C, F[b]
U.S. 95 (Las Vegas to Mercury)	B
Apex/Dry Lake	
I-15 (to Craig interchange	A
I-15 (in Las Vegas)	E and F[b]
U.S. 95 (in Las Vegas)	E and F[b]
U.S. 95 (Las Vegas to Mercury)	B

a. Source: DIRS 103225-DOE (1998, pp. 3-1 to 3-14).
b. Does not consider the Las Vegas Beltway.

3.3 Affected Environment at Commercial and DOE Sites

In response to public comments, DOE has revised Section 3.3 to provide more information on the methodology the Department used to determine baseline conditions at the 72 commercial and 5 DOE sites evaluated under the No-Action analysis. The revisions include added information on the individual site environmental factors (Section 3.3.1) and augmented information on regional environmental factors (Section 3.3.2). In providing this new information, DOE changed the section numbers for the information that appeared in the Draft EIS.

The No-Action Alternative analyzes the impacts of not constructing and operating a monitored geologic repository at Yucca Mountain. It assumes that the spent nuclear fuel and high-level radioactive waste would remain at commercial and DOE sites throughout the United States. This section describes baseline environmental factors at commercial and DOE sites including land use requirements, radiological effluents, worker and offsite populations, and occupational and public radiation doses. These factors provide a basis for comparison of impacts with the Proposed Action and the No-Action Alternative.

In addition to the site environmental factors, this section also includes regional environmental factors for five regions of the United States, including climate, groundwater, waterways, and potentially affected populations. These regional parameters provide the baseline information necessary for estimating potential impacts resulting from the No-Action Alternative Scenario 2 described in Chapter 7 of the EIS.

3.3.1 SITE ENVIRONMENTAL FACTORS

3.3.1.1 COMMERCIAL SITES

At present, there are 103 operating commercial nuclear powerplants at 69 sites in 31 of the contiguous United States. In addition, three sites (Trojan in Oregon, and Humboldt Bay and Rancho Seco in California) have reactors in various stages of decommissioning. The locations of the 72 commercial nuclear powerplants evaluated in this EIS are shown in Figure 3-33. Approximately half of these sites contain two or three nuclear units. There are no commercial nuclear powerplants in Alaska or Hawaii.

3.3.1.1.1 *Land Use and Ownership*

Typically, nuclear powerplant sites and the surrounding areas are flat-to-rolling countryside in wooded or agricultural areas. More than half of the sites have 80-kilometer (50-mile) population densities of fewer than 200 persons per square mile, and more than 80 percent have 80-kilometer densities of fewer than 500 persons per square mile (DIRS 101899-NRC 1996, Section 2.2.1, p. 2-2). The most notable exception is the Indian Point Station, which is within 80 kilometers of New York City, which has a population density of more than 2,000 persons per square mile.

Site areas range from 0.34 square kilometer (84 acres) for the San Onofre Nuclear Generating Station in California to 120 square kilometers (30,000 acres) for the McGuire Nuclear Station in North Carolina. More than half of the plant sites encompass 2 to 8 square kilometers (500 to 2,000 acres). Larger land use areas are usually associated with plant cooling systems that include reservoirs, artificial lakes, and buffer zones. Typically, 0.2 to 0.4 square kilometer (50 to 100 acres) might actually be disturbed during plant construction. Other land commitments can amount to many tens of square kilometers for transmission line rights-of-way and cooling lakes (if used).

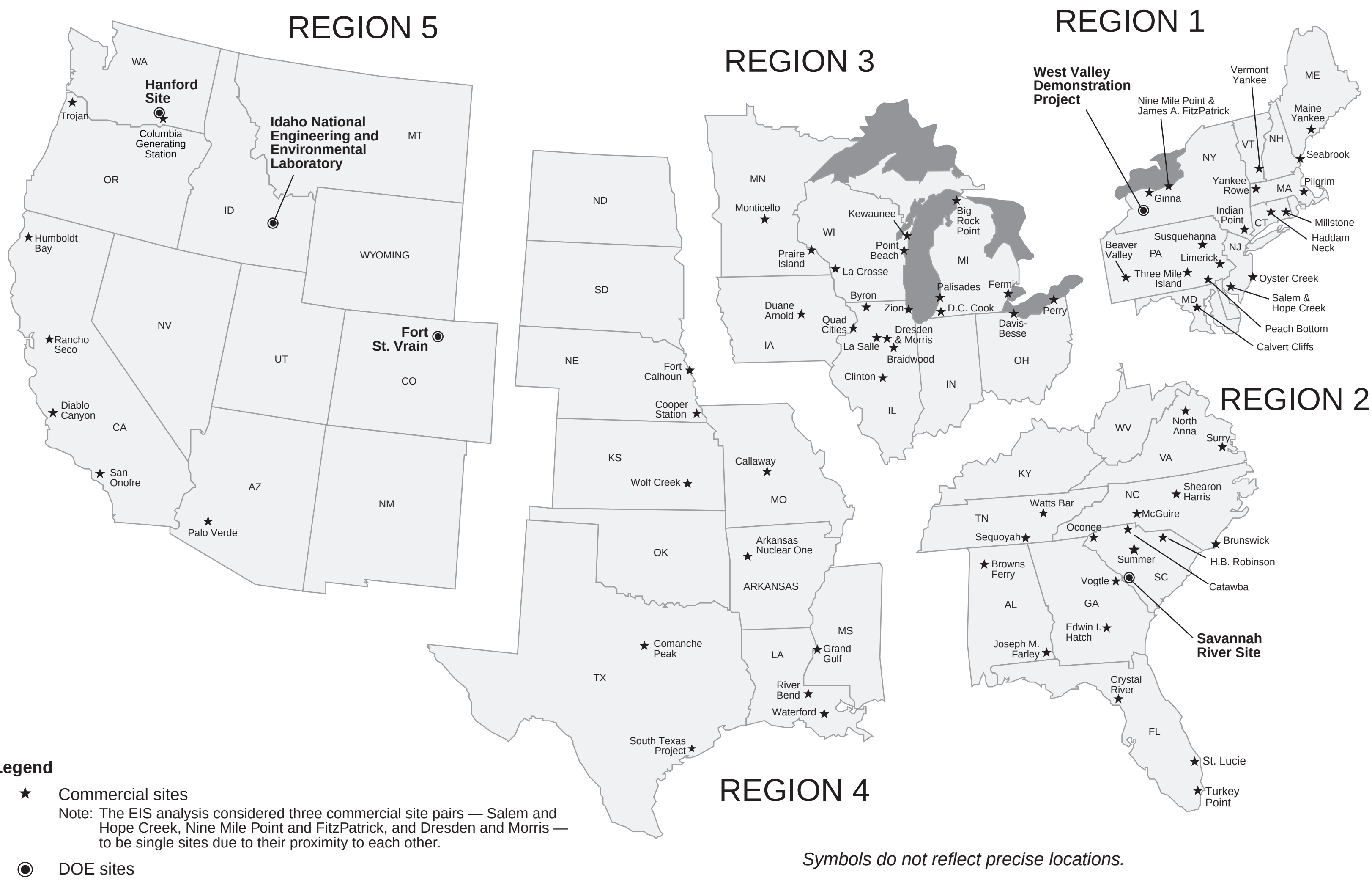
In general, these sites are owned and maintained by the investor owned utilities (sites operated by the Tennessee Valley Authority are Federally owned) that operate the associated power plants and control egress to the sites to protect the health and safety of the public.

3.3.1.1.2 *Socioeconomic Environment*

Although the size of the workforce varies considerably among sites, the average permanent staff size at a nuclear powerplant ranges from 800 to 2,400 people, depending on the number of operating units at the site (DIRS 101899-NRC 1996, Section 2.3.8.1, p. 2-26). In rural or low-population communities, the number of permanent jobs can represent a substantial portion of the local workforce.

In addition to the permanent workforce, many temporary workers are required for tasks that occur during refueling and maintenance outages. Between 200 and 900 additional workers can be employed during these outages to perform the normal maintenance work. Although these temporary workers are in the community for only a short time (usually 1 to 2 months a year), they can have a substantial effect on the area (DIRS 101899-NRC 1996, Section 2.3.8.1, p. 2-27).

In addition to direct employment, plant subcontractors and service industries in the area provide hundreds of indirect jobs. In rural communities, industries that provide this number of jobs at relatively high wages are major contributors to the local economy. In addition to the beneficial effect of these jobs, plant purchasing and worker spending can generate considerable income for local businesses (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).



Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Source: Modified from DIRS 101911-Poe (1998, p. 2).

Figure 3-33. Commerical and DOE sites in each No-Action Alternative analysis region.

A nuclear powerplant represents an investment of several billion dollars. Such an asset on the tax rolls is extraordinary for rural communities and can constitute the major source of local revenues for small or remote taxing jurisdictions. This revenue often enables higher quality and more extensive public services with lower tax rates to the citizens (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).

For these reasons, nuclear powerplants can have a significant positive effect on the local community environment. These effects are stable and long-term. Because these effects generally enhance the economic structure of the local community, nuclear powerplants become a major positive contributor to the local area (DIRS 101899-NRC 1996, Section 2.3.8.2, p. 2-28).

3.3.1.1.3 *Radioactive Effluents*

During normal operations, nuclear powerplants release small amounts of radioactive materials to the environment through atmospheric and aquatic pathways. These radioactive materials, released under controlled conditions, include fission and activation products. Releases to the atmosphere consist primarily of the noble gases and some of the more volatile materials like tritium, isotopes of iodine, and cesium. Releases to aquatic pathways consist primarily of nonvolatile fission and activation products such as isotopes of cesium and cobalt. After appropriate holdup and processing, these materials are monitored carefully before and during releases to determine whether the licensed release limits can be met (for example, 10 CFR Part 20, Appendix I to 10 CFR Part 50, 10 CFR 50.36a, and 40 CFR Part 190).

In 1993 (the last year for which information is readily available), boiling-water and pressurized-water reactors released about 31,000 and 28,000 curies, respectively, of fission and activation gases to the atmosphere (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 1 and 2, pp. 6-12). Thus, the estimated average atmospheric release per boiling-water reactor and pressurized-water reactor was 760 and 380 curies per year, respectively.

In addition, boiling-water reactors and pressurized-water reactors released 0.75 and 0.30 curies, respectively, of iodine-131 and particulates to the atmosphere (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 3 and 4, pp. 12-17). This resulted in boiling-water reactor and pressurized-water reactor average unit releases of 0.018 and 0.0041 curies, respectively.

Liquid releases of tritium in 1993 for boiling-water reactors and pressurized-water reactors totaled about 530 and 36,000 curies, respectively (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 5 and 6, pp. 18-24), and about 11 and 35 curies, respectively (DIRS 155108-Tichler, Doty, and Lucadamo 1995, Tables 7 and 8, pp. 24-29), of mixed fission and activation products.

3.3.1.1.4 *Occupational and Public Health and Safety*

Occupational Radiation Exposures

Nuclear plant workers who conduct activities involving radioactively contaminated systems or who work in radiation areas can be exposed to radiation. Most of the occupational radiation dose to such workers results from external radiation rather than internal exposure to inhaled or ingested radioactive materials. Pursuant to reporting requirements of 10 CFR 20.2206, the Nuclear Regulatory Commission received annual reports from 104 licensees that operated commercial nuclear power reactors in 1999. These reports consisted of radiation exposure records for each monitored individual. The reports are analyzed for trends and summarized in annual reports (DIRS 155099-Karagiannis and Hagemeyer 2000, all) in terms of collective dose and the distribution of dose among the monitored individuals.

In 1999, the total collective occupational dose for all operating commercial reactors was almost 14,000 person-rem or an average per licensee of 131 person-rem (DIRS 155099-Karagiannis and Hagemeyer 2000, Table 3.2, p. 3-5). This total collective dose was received by about 114,000 monitored workers for an average annual individual dose of 120 millirem, which is about 40 percent of the average background radiation dose for the United States, as listed in Table 3-30. However, of the 114,000 monitored workers, about half (55,000 workers) had no measurable dose. Of the approximately 59,000 workers who had a measurable dose, the estimated annual average radiation exposure was 230 millirem, or about 77 percent of the national average background radiation dose of 300 millirem.

In addition to nuclear powerplant licensees, in 1999 the Nuclear Regulatory Commission received annual radiation exposure reports from two Independent Spent Nuclear Storage Facility operators. The reported annual collective dose for these two licensees was 5 person-rem received by 86 monitored individuals, for an annual average of 60 millirem. Of the monitored individuals, only 33 received measurable radiation doses for an annual average of 150 millirem. These doses represent 20 and 50 percent, respectively, of the national average background radiation dose of 300 millirem.

Public Radiation Exposures

Releases of radioactive materials from nuclear power reactors result in radiation doses to humans that are small in relation to doses from natural background radiation. Persons can be exposed to radiation from nuclear power reactors through atmospheric and aquatic pathways. When an individual is exposed through one of these pathways, the dose is determined by the amount of the radioactive material a person could inhale or ingest. The amount of radioactive material inhaled or ingested is determined by the exposure time and the radioactive material concentrations in the various environmental media. The resulting dose is determined by radionuclide-specific dose conversion factors, which are based on physical decay and metabolic properties of the radioactive material in the body.

The major exposure pathways include the following:

- Inhalation of contaminated air
- Drinking milk or eating meat from animals that graze on open pasture on which radioactive contamination might fall
- Eating vegetables grown near the site
- Drinking water or eating fish caught near the point of discharge of liquid effluents

Other less important exposure pathways include external irradiation from surface deposition; consumption of animals that drink irrigation water that might contain liquid effluents; consumption of crops grown near the site using irrigation water that might contain liquid effluents; shoreline, boating, and swimming activities; and direct radiation to offsite individuals.

In 1992 (the last year for which information is readily available), the estimated total population doses for populations living within 80 kilometers (50 miles) of operating nuclear power reactors were 32 person-rem by waterborne pathways and 15 person-rem by airborne pathways, for a total of 47 person-rem (DIRS 155092-Aaberg and Baker 1996, Table 1.4, p. 1.9). However, estimated population dose commitments for the waterborne and airborne pathways varied widely among the sites. The total dose commitments from both pathways for individual sites varied from a high of 3.7 person-rem to a low of 0.0015 person-rem. The arithmetic mean for the total dose from liquid pathways (0.44 person-rem) and airborne pathways (0.21 person-rem) was 0.66 person-rem (DIRS 155092-Aaberg and Baker 1996, p. 1.11). The estimated average annual dose to the offsite individual living within 80 kilometers was 0.0003 millirem, which is a very small fraction of the average annual dose from natural background radiation of 300 millirem in the United States.

In addition to average population doses, maximally exposed individual doses were estimated for commercial nuclear power sites for comparison with the 10 CFR Part 50, Appendix I, numerical guides for design objectives [10 CFR 50.34a(a)], which require nuclear powerplant licensees to design and operate their facilities in a manner that maintains offsite doses from liquid and atmospheric effluents *as low as reasonably achievable*. For the more than 70 sites reporting in 1992, the arithmetic mean of the maximum annual dose from atmospheric pathways for an offsite individual living at the nearest residence was about 0.012 millirem from releases of noble gases and 0.27 millirem to any organ (thyroid, lung, etc.) from releases of iodines and particulate material. For the liquid pathways, the arithmetic mean of the *maximally exposed individuals* for all reporting sites was about 0.12 millirem (DIRS 155092-Aaberg and Baker 1996, Table 1.4, p. 1.9).

For the waterborne pathways, tritium, zinc-65, and isotopes of cesium accounted for 31, 14, and 43 percent of the total dose, respectively. For the airborne pathways, tritium and isotopes of xenon accounted for 44 and 46 percent of the dose, respectively (DIRS 155092-Aaberg and Baker 1996, Table 1.8, pp. 1.17 through 1.22).

3.3.1.2 DOE SITES

This EIS focuses on the five DOE sites at which spent nuclear fuel and high-level radioactive waste currently exists or where existing Records of Decision have authorized placement of these materials (see Chapter 7, Section 7.2 for details). The five sites are the Hanford Site, the Idaho National Engineering and Environmental Laboratory, Fort St. Vrain (spent nuclear fuel only), the West Valley Demonstration Project (high-level radioactive waste only), and the Savannah River Site (Figure 3-33).

3.3.1.2.1 *Land Use and Ownership*

Of the five DOE sites that manage spent nuclear fuel and high-level radioactive waste, three (Hanford Site, Idaho National Engineering and Environmental Laboratory, Savannah River Site) are on large tracts of Federally owned land ranging from 2,300 square kilometers (890 square miles) for Idaho National Engineering and Environmental Laboratory to 800 square kilometers (310 square miles) for the Savannah River Site. On these three sites, most of the land is undeveloped or forest management areas. These undeveloped areas serve as buffer zones between the operating areas and the public. Access to these sites is controlled for national security purposes to prevent ingress by unauthorized personnel.

The Fort St. Vrain Independent Spent Nuclear Fuel Installation and West Valley Demonstration Project are on much smaller tracts of land, 3.8 acres and 220 acres, respectively, which are mostly developed but are surrounded by low-population-density lands used mostly for agricultural and residential purposes.

3.3.1.2.2 *Socioeconomic Environment*

Because of their large employment base, the Hanford Site, Idaho National Engineering and Environmental Laboratory, West Valley Demonstration Project, and Savannah River Site represent a substantial portion of their respective local workforces. For example, in December 1997 the Hanford Site employed almost 11,000 DOE and contractor personnel, which represented 13 percent of the total employment in the area (DIRS 156931-DOE 2000, p. 4-101). Similarly, in 1998 Idaho National Engineering and Environmental Laboratory and Savannah River Site employed 8,100 and 14,000 workers, respectively, which represented about 7 percent of their local area workforces (DIRS 156914-DOE 2000, all). In 1993, the West Valley Demonstration Project employed more than 1,000 DOE and contract workers and was the largest local employer; these workers represented almost 4 percent of the local workforce (DIRS 101729-DOE 1996, p. 4-58).

In 1995, approximately 230 persons worked at the Fort St. Vrain site. Of these, approximately 16 full-time-equivalent personnel worked on the Independent Spent Fuel Storage Facility (DIRS 103213-DOE 1996, Appendix E, Section 3, pp. 3-53 and 54). Based on the 1980 census, the population within an 8 kilometer (5-mile) radius of the site was 3,148, with 1,662 residing in the Town of Platteville. The projected population for 2012 (through the 20-year license) for this area will be 4,526, with 3,040 residing in Platteville. However, even with this relatively small local workforce, the 16 workers and the DOE site would have minimal impact.

In addition to base employment, DOE sites contribute to the local economic conditions through the creation of indirect employment and through the purchase of goods and services from local firms.

3.3.1.2.3 *Radioactive Effluents*

As a result of ongoing process and *remediation* activities, most DOE sites routinely release quantities of radioactive materials to the atmosphere and surface waters that eventually enter the surrounding environment. These effluents are carefully monitored at their points of discharge to ensure that releases remain within limits specified by DOE Orders and applicable state and Federal statutes and regulations.

Radioactive materials released from DOE sites consist of fission and activation products (such as tritium, cesium, strontium, iodine, and krypton), transuranics (such as plutonium and americium), and source material (such as uranium). Atmospheric releases consist primarily of tritium and noble gases (such as krypton and argon), and liquid releases consist primarily of tritium with much smaller quantities of fission products and transuranics. The Idaho National Engineering and Environmental Laboratory typically does not release radioactive liquid effluents off the site. Rather, liquid effluents are sent to two plastic-lined evaporation ponds (DIRS 156914-DOE 2000, Section 7.1, p. 7-3) that prevent percolation of contaminated water into the ground and eventual release to the *accessible environment*. In addition, the Hanford Site 200-Area facilities discharge radioactive liquid effluents to the 616-A-Crib (also known as the State-Approved Land Disposal Site) rather than directly to the Columbia River (DIRS 156931-DOE 2000, Section 3.1.3, p. 3.6). The Fort St. Vrain site does not have atmospheric or liquid effluents (DIRS 155101-DOE 1998, Section 2.3.4.1, p. 2-25 and Section 2.4.2, p. 2-35) because the spent nuclear fuel is stored in sealed canisters and is not typically handled or processed.

In 1999, the four DOE sites with radioactive effluents discussed in this section released about 92,000 *curies* of fission and activation products to the atmosphere (DIRS 156914-DOE 2000, Table 7-1, p. 7-4; DIRS 156931-DOE 2000, Table 3.1.1, p. 3.6; DIRS 155094-Arnett and Mamatey 2000, Table 4, p. 13; DIRS 154284-WVNS 2000, Tables D-2 through D-11, pp. D-4 through D-12). Most of these releases occurred at the Savannah River Site, which released about 89,000 curies. The Savannah River Site atmospheric releases consisted almost entirely of tritium (about 52,000 curies) and noble gases (about 37,000 curies). In addition, the four sites released 0.0025 curie of transuranics and 0.048 curie of source material to the atmosphere.

In 1999, the DOE sites released about 6,400 curies of fission and activation products in liquid effluents (DIRS 156914-DOE 2000, Table 7-2, p. 7-5; DIRS 156931-DOE 2000, Tables 3.1.3 and 3.1.4, p. 3.7; DIRS 155094-Arnett and Mamatey 2000, Table 6, p. 22; and DIRS 154284-WVNS 2000, Table C-1, p. c-3). More than 99 percent of these releases consisted of tritium, and most (about 6,300 curies) occurred at the Savannah River Site.

3.3.1.2.4 *Occupational and Public Health and Safety*

Occupational Radiation Exposures

In 1999, DOE reported a total workforce (including contractors) of approximately 130,000 individuals (DIRS 155091-DOE 1999, Exhibit 3-1, p. 3-2). Of these individuals, about 113,000 were monitored for potential radiation exposure. Only about 17,000 received measurable doses. The collective dose is the sum of the doses received by all individuals who had measurable doses, and is reported in person-rem. The collective dose is an indicator of the overall radiation exposure at DOE facilities and includes doses to all DOE employees, contractors, and visitors. DOE monitors the collective dose as one measure of the overall performance of radiation protection programs to keep individual and collective exposures as low as reasonably achievable.

For the five sites discussed in this section, DOE reported a total collective dose of about 380 person-rem for 1999 (DIRS 155091-DOE 1999, Exhibit 3-17, p. 3-17). This dose was received by almost 6,000 individuals with measurable doses, for an average annual dose of about 60 millirem per person. This dose represents 20 percent of the national average background dose of 300 millirem. The Fort St. Vrain site reported no measurable doses for 1999.

Public Radiation Exposures

In a manner similar to that described in Section 3.3.1.1.4 for commercial sites, DOE estimates collective and individual doses for populations living within 80 kilometers (50 miles) of their operations facilities. In 1999, for the five DOE sites discussed in this section, the total estimated offsite population dose was about 7.1 person-rem. This dose was received by a total 80-kilometer population of about 2.5 million people for an average dose of about 0.003 millirem per person, which is a very small fraction of the average annual dose from natural background radiation of 300 millirem in the United States (DIRS 156914-DOE 2000, Table 8-3, p. 8-9; DIRS 156931-DOE 2000, Table 5.0.2, p. 5.9; DIRS 155090-Arnett and Mamatey 2000, Table 7-2, p. 118, p. 121; DIRS 155094-Arnett and Mamatey 2000, Table 32, p. 125; DIRS 154284-WVNS 2000, Table 4-2, p. 4-7). Most of this collective dose (6.6 person-rem) was received by persons living around and downstream of the Savannah River Site and is attributed to atmospheric and liquid releases of tritium (3.5 person-rem) (DIRS 155094-Arnett and Mamatey 2000, Table 41, p. 135 and Table 48, p. 144). Fort St. Vrain reported that radioactive effluents and direct radiation from the site in 1999 did not contribute to any increase in offsite doses (DIRS 155093-Newkirk and Hall 2000, p. 7).

In addition to average population doses, DOE estimated doses for the hypothetical maximally exposed offsite individual. For the four sites with reported offsite doses, the maximally exposed offsite individual received a maximum dose of 0.28 millirem (DIRS 155100-DOE 1999, p. 8-4; DIRS 155097-DOE 1999, p. 5.4; DIRS 155090-Arnett and Mamatey 2000, p. 122; DIRS 154284-WVNS 2000, Table 4-2, p. 4-7), primarily from atmospheric and liquid releases of tritium (0.10 millirem) and liquid releases of cesium-137 (0.13 millirem) (DIRS 155094-Arnett and Mamatey 2000, Table 42, p. 136, and Table 45, p. 141).

3.3.2 REGIONAL ENVIRONMENTAL FACTORS

For analytic purposes, DOE divided the country into five regions (see Figure 3-33). This section describes the affected environment for each region that reflects the average or mean conditions of the sites in the region. The affected environment includes spent nuclear fuel and high-level radioactive waste inventories, climatic parameters, groundwater flowrates, downstream surface-water users, and downstream surface-water flowrates. In all cases, DOE used data consisting of average or mean conditions from actual sites to develop hypothetical sites.

To develop the hypothetical sites, DOE divided the generator sites among the five regions (Figure 3-33). Climate varies considerably across the United States. Radionuclide release rates would depend primarily on the interaction of climate and materials. DOE analyzed release rates for a hypothetical site in each region that was a mathematical representation of the actual sites in that region. The development process for the hypothetical site used weighted values for material inventories, climate, and groundwater flow information from each actual site to ensure that the results of the analyses of the hypothetical site were comparable to the results for each actual site, if analyzed independently. Similarly, the process constructed downstream populations of water users and river flow for the hypothetical sites from population and river flow data for actual sites, so they reflect the populations downstream of actual storage facilities and the actual amount of water those populations use.

3.3.2.1 REGIONAL INVENTORIES OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

Table 3-61 lists the Proposed Action quantities of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste in each of the five regions. The information in the table is a projection of quantities and forms that would exist at a point in the future, not as they currently exist. For example, high-level radioactive waste is listed in the table as having gone through a vitrification process with subsequent packaging in canisters, as if ready for disposal in a repository.

Table 3-61. Proposed Action quantities of spent nuclear fuel (metric tons of heavy metal) and canisters of high-level radioactive waste in each geographic region.[a,b]

Region	Commercial spent nuclear fuel[c,d]	DOE spent nuclear fuel[e]	High-level radioactive waste[f,g]
1	16,800	0	300
2	18,900	30	6,000
3	14,700	0	0
4	7,200	0	0
5	5,400	2,300	2,000
Totals	63,000	2,300	8,300

a. Source: Appendix A.
b. Totals might differ from sums due to rounding.
c. Analyzed as stored on surface, as shown on Chapter 2, Figures 2-32, 2-33, and 2-34.
d. Includes plutonium in mixed-oxide spent nuclear fuel, which is assumed to behave like other commercial spent nuclear fuel.
e. A representative or surrogate fuel that consisted primarily of N-reactor fuel.
f. Includes plutonium in can-in-canister.
g. Historically, a canister of high-level radioactive waste has been assumed to be equivalent to about 0.5 MTHM (see Appendix A, Section A.2.3.1).

3.3.2.2 CLIMATIC FACTORS AND MATERIAL

DOE assumed that a single hypothetical site in each region would store all the spent nuclear fuel and high-level radioactive waste in each region. Such a site does not exist, but DOE used it for this analysis. To ensure that the calculated results of the regional analyses reflected the appropriate inventory, facility and material degradation, and radionuclide transport, DOE developed the spent nuclear fuel and high-level radioactive waste inventories, engineered barriers, and environmental parameters for the hypothetical site from data from the actual sites in that region. Weighting criteria accounted for the different amounts and types of spent nuclear fuel and high-level radioactive waste at each site, so the results of the analyses of the hypothetical site were representative of the sum of the results if DOE had modeled each actual site independently. If there are no storage areas in a particular part of a region, DOE did not analyze the environmental parameters of that part (for example, there are no storage facilities in the Upper Peninsula of Michigan, so the analysis for Region 3 did not include environmental parameters from cities in the Upper Peninsula). In addition, if the storage area would not affect drinking water (for example, groundwater near the Calvert Cliffs Nuclear Generating Plant outcrops to the Chesapeake Bay), the regional hypothetical storage facility did not include their fuel inventories.

The following climate parameters are important to material degradation times and rates of release:

- Precipitation rate (amount of precipitation per year)
- Rain days (percent of days with measurable precipitation)

- Wet days (percent of year that included rain days and days when the relative humidity was greater than 85 percent)
- Temperature
- Precipitation chemistry (pH, chloride anions, and sulfate anions)

Table 3-62 lists the regional values for each parameter. Appendix K contains more information on the selection and analysis of these parameters.

Table 3-62. Regional environmental parameters.

Region	Precipitation rate (centimeters per year)[a]	Percent rain days (per year)	Percent wet days (per year)	pH	Precipitation chemistry: Chloride anions (weight percent)	Precipitation chemistry: Sulfate anions (weight percent)	Average temperature (°C)[b]
1	110	30	31	4.4	6.9×10^{-5}	1.5×10^{-4}	11
2	130	29	54	4.7	3.9×10^{-5}	9.0×10^{-5}	17
3	80	33	42	4.7	1.6×10^{-5}	2.4×10^{-4}	10
4	110	31	49	4.6	3.5×10^{-5}	1.1×10^{-4}	17
5	30	24	24	5.3	2.1×10^{-5}	2.5×10^{-5}	13

a. To convert centimeters to inches, multiply by 0.3937.
b. To convert degrees Centigrade to degrees Fahrenheit, add 17.78 and then multiply by 1.8.

3.3.2.3 GROUNDWATER PARAMETERS

Most of the radioactivity and metals from degraded material would seep into the groundwater and flow with it to surface outcrops to rivers or streams. Therefore, the analysis had to account for the groundwater characteristics at each site, including the time it takes the water to move through the unsaturated zone and the aquifer. The analysis assumed that the storage facilities would be 490 meters (1,600 feet) up the groundwater gradient from the hypothetical reactor and used this assumption to calculate the time it would take contaminants to reach surface water. Table 3-63 lists the ranges of groundwater flow times in each region. Appendix K contains more information on the sources of groundwater data.

Table 3-63. Ranges of flow time (years) for groundwater and contaminants in the unsaturated and saturated zones in each region.

Region	Contaminant K_d[a] (milliliters per gram)	Unsaturated zone: Water flow time	Unsaturated zone: Contaminant flow time	Saturated zone: Groundwater flow time	Saturated zone: Contaminant flow time	Total contaminant flow time
1	0[b] - 100	0.7 - 4.4	0.4 - 2,100	0.3 - 56	10 - 5,000	10 - 6,000
2	10 - 250	0.6 - 10	35 - 5,000	3.3 - 250	11 - 310,000	460 - 310,000
3	10 - 250	0.5 - 14	32 - 1,500	1.3 - 410	9 - 44,000	65 - 45,000
4	10 - 100	0.2 - 7.1	110 - 2,300	3.9 - 960	300 - 520,000	460 - 520,000
5	0 - 10	0.9 - 73	14 - 4,700	1.7 - 170	0 - 25,000	200 - 26,000

a. K_d = equilibrium adsorption coefficient.
b. The K_d would be 0 if there was no soil at the site.

3.3.2.4 AFFECTED WATERWAYS

Most of the estimated population dose for the No-Action Alternative would be a result of drinking contaminated surface water. The first step in determining the population dose was to identify the waterways that receive groundwater from beneath existing storage facilities (Figure 3-34) and the number of public drinking water systems that draw water from the potentially contaminated waterways

Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: The Great Lakes and the St. Lawrence Seaway are considered major waterways.

Source: Modified from DIRS 101911-Poe (1998, p. 13).

Figure 3-34. Major waterways near commercial and DOE sites.

(Table 3-64). DOE calculated the river flow past each population center (Section 3.3.2.5) along each river, and used this number in the calculation to determine dose to the population.

3.3.2.5 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-64 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.

Table 3-64. Public drinking water systems and the populations that use them in the five regions.[a]

Region	Drinking water systems	Population
1	85	10,000,000
2	150	5,600,000
3	150	12,000,000
4	95	600,000
5	6	2,800,000
Totals	***486***	***31,000,000***

a. Sources: Based on current information and the 1990 census.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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103070	ACGIH 1999	ACGIH (American Conference of Governmental Industrial Hygienists) 1999. *1999 TLVs® and BEIs®, Threshold Limit Values for Chemical Substances and Physical Agents, Biological Exposure Indices.* Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists. TIC: 243476.
156932	AIET 2000	AIET (American Indian Ethnography Team) 2000. *Preliminary Cultural Assessment of Wildhorse Spring and the Willow Springs Complex on and Near the Nellis Air Force Range.* Las Vegas, Nevada: Nellis Air Force Base.
102043	AIWS 1998	AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.

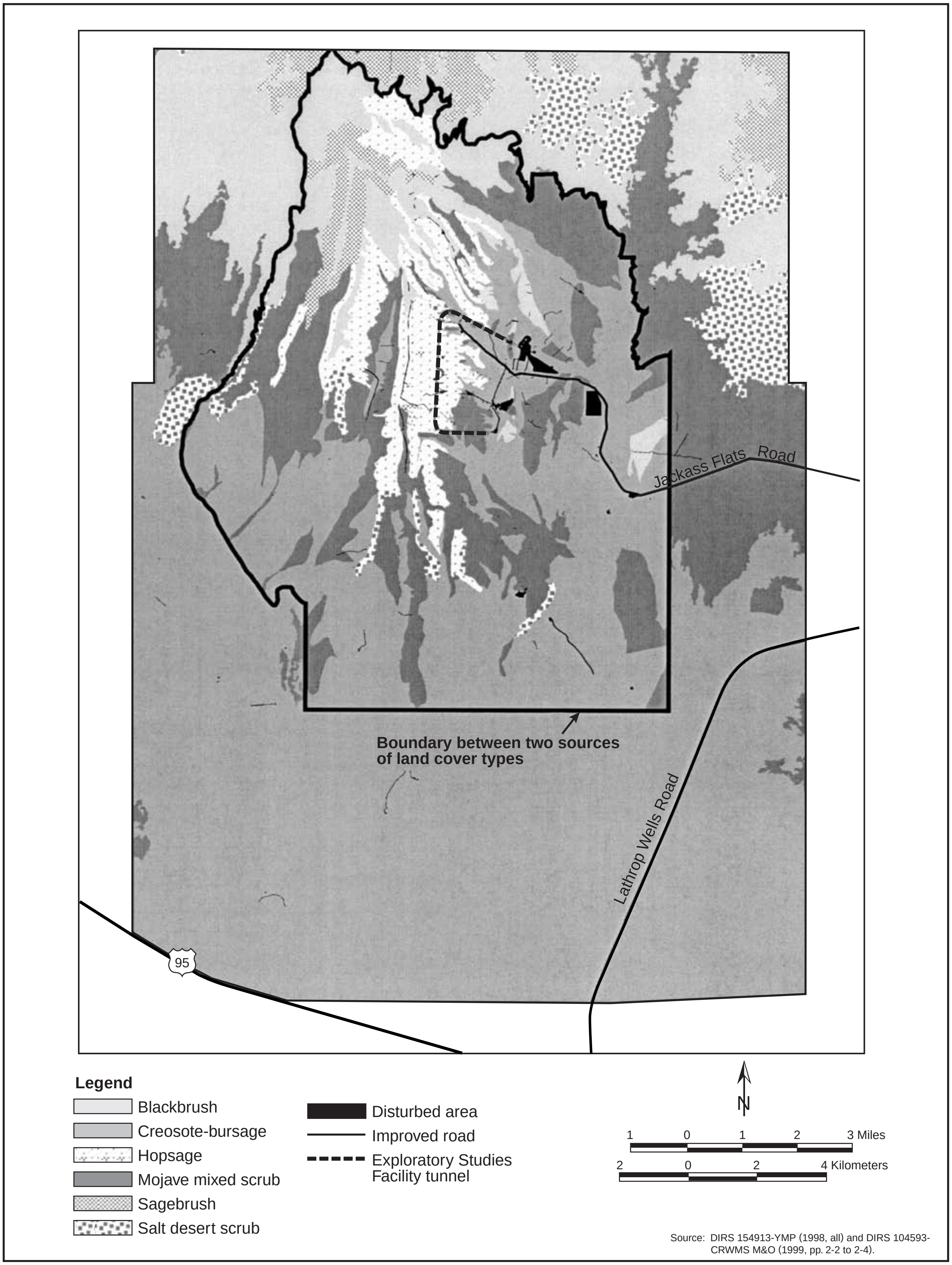


Figure 3-21. Land cover types in the analyzed land withdrawal area.

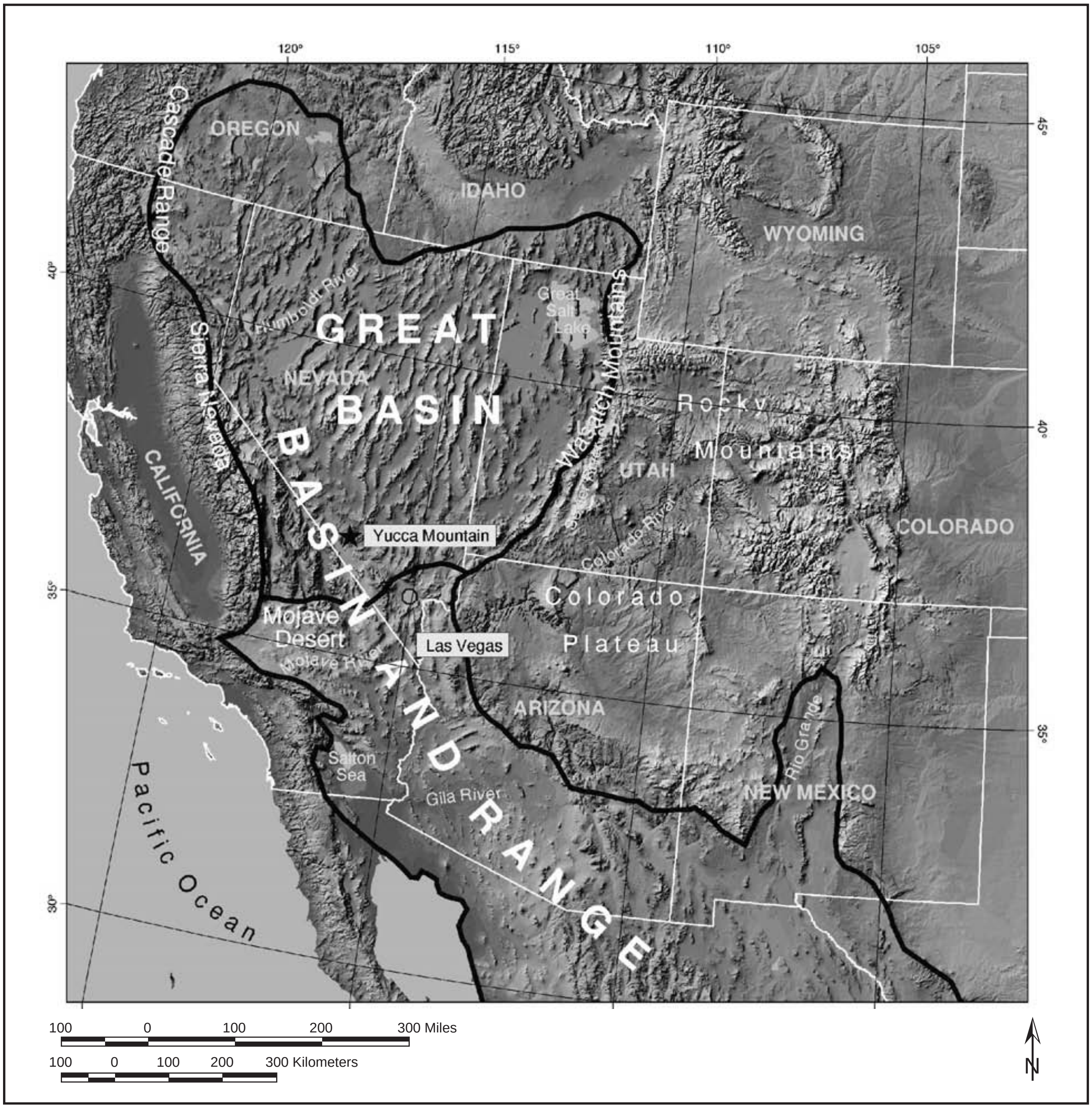


Figure 3-4. Basin and Range Physiographic Province and Great Basin Subprovince.

upland, 6 to 10 kilometers (4 to 6 miles) wide and 35 kilometers (22 miles) long (DIRS 151945-CRWMS M&O 2000, pp. 2.2-1 and 4.4). This mountain is part of a volcanic plateau formed between about 14 million and 11.5 million years ago (DIRS 100075-Sawyer et al. 1994, p. 1304) known as the Southwestern Nevada volcanic field. Although Yucca Mountain is a product of both volcanic activity and faulting, the region exhibits evidence of a complex history of *deformation* associated with past interactions of crustal segments (plates) (DIRS 151945-CRWMS M&O 2000, p. 4.2-1). Geologic relations indicate that many of the current features and the landscape in the Yucca Mountain region formed between 12.7 million and 11.7 million years ago (DIRS 151945-CRWMS M&O 2000, p. 4.4-2). Remnants of the Timber Mountain caldera (one of the centers of the southwestern Nevada volcanic field from which most of the volcanic rocks on the surface of Yucca Mountain were erupted) and other calderas are north of Yucca Mountain (see Figure 3-5).

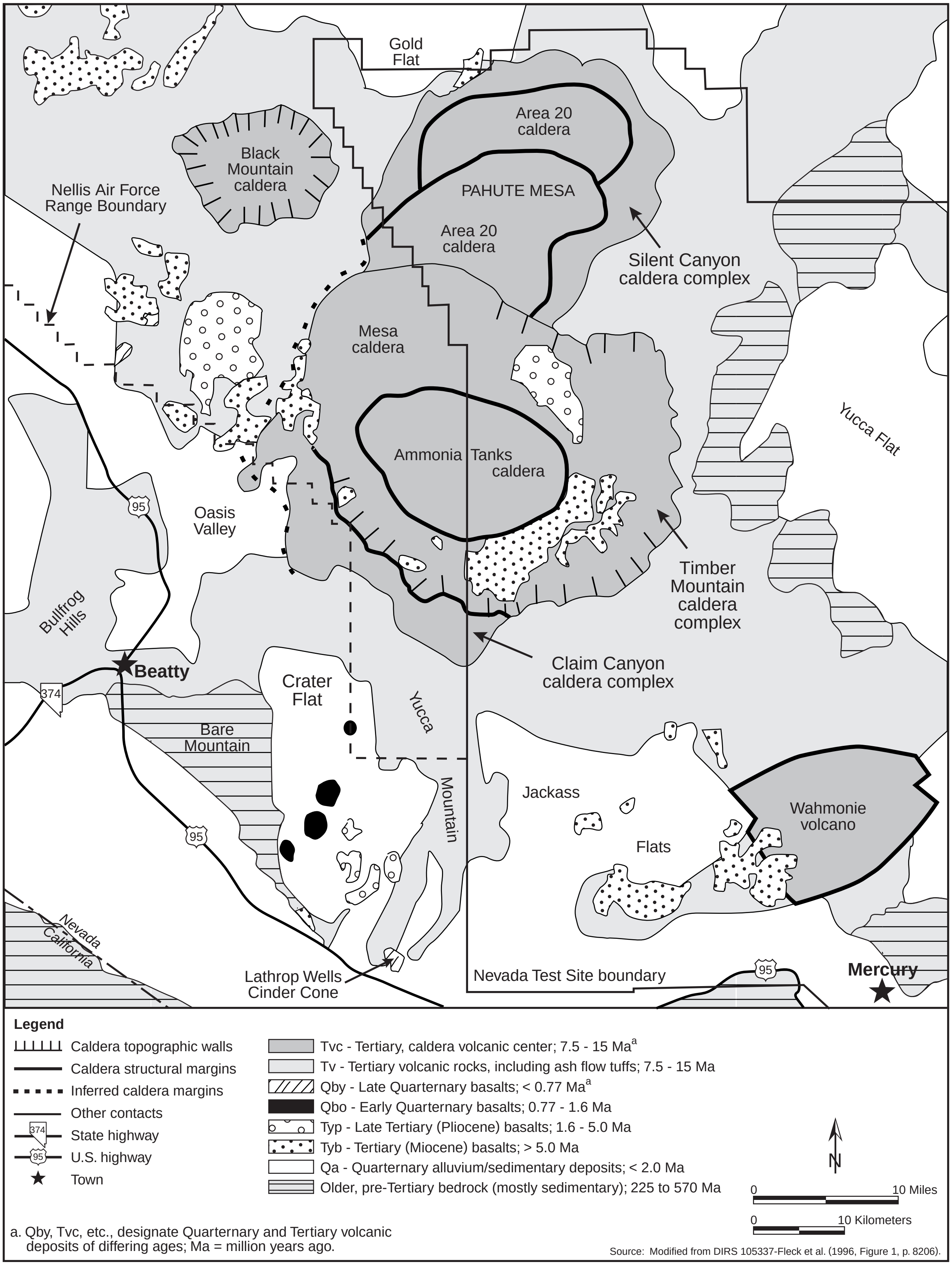


Figure 3-5. Simplified geologic map showing calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

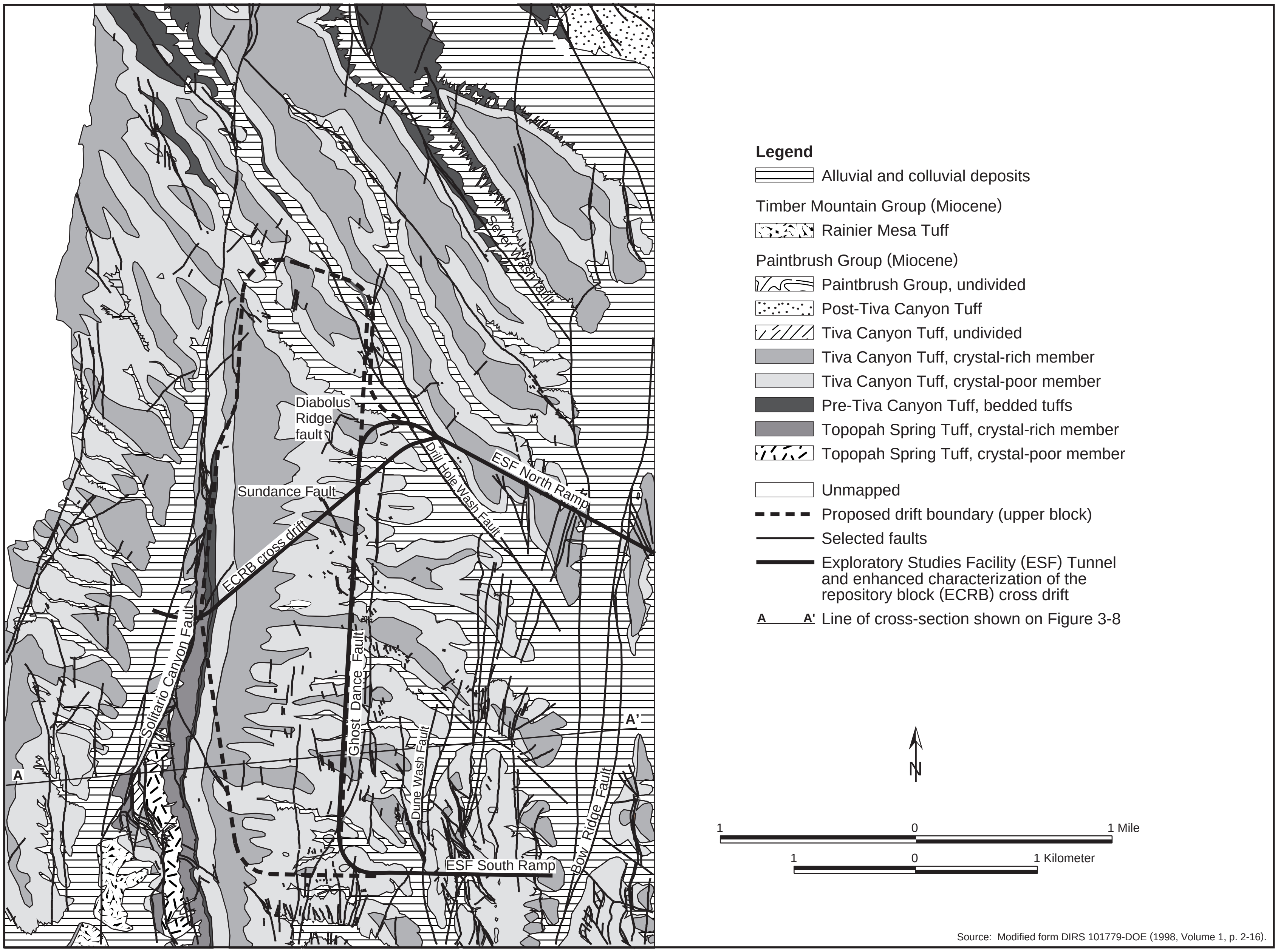
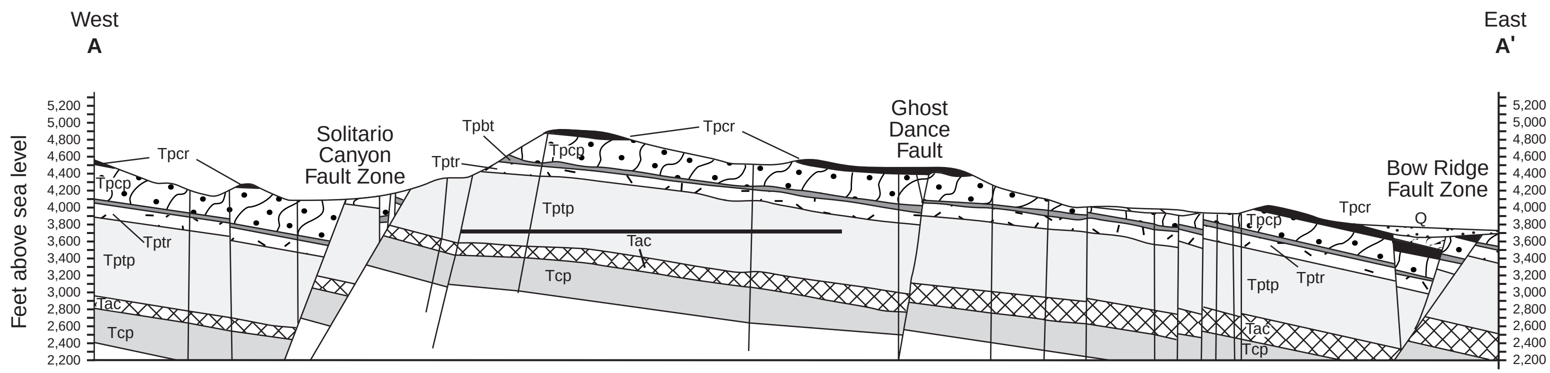


Figure 3-7. General bedrock geology of the proposed repository Central Block Area.



Legend

Q - Alluvial and colluvial deposit

Timber Mountain Group

Tmr - Rainier Mesa Tuff

Paintbrush Group

Tpcr - Tiva Canyon Tuff, crystal-rich member

Tpcp- Tiva Canyon Tuff, crystal-poor member

Tpbt - Pre-Tiva Canyon Tuff, bedded tuffs

Tptr - Topopah Spring Tuff, crystal-rich member

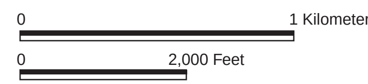
Tptp - Topopah Spring Tuff, crystal-poor member

Tac - Calico Hills Formation

Crater Flat Group

Tcp - Prow Pass Formation

Approximate location of proposed repository



Note: Line of cross-section indicated on Figure 3-7. Faults consistent with Figure 3-10.

Source: Modified from DIRS 101779-DOE (1998, Volume 1, p. 2-17) and DIRS 153849-DOE (2001, Figure 4-9, p. 4-38).

Figure 3-8. Simplified geologic cross-section of Yucca Mountain, west to east.

(Table 3-64). DOE calculated the river flow past each population center (Section 3.3.2.5) along each river, and used this number in the calculation to determine dose to the population.

Table 3-64. Public drinking water systems and the populations that use them in the five regions.[a]

Region	Drinking water systems	Population
1	85	10,000,000
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3	150	12,000,000
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5	6	2,800,000
Totals	***486***	***31,000,000***

a. Sources: Based on current information and the 1990 census.

3.3.2.5 AFFECTED POPULATIONS

After identifying the affected waterways, DOE identified the populations that get their drinking water from those waterways. The total population using the river was expressed as number of people per cubic foot per second. If a river system traverses more than one region (for example, the Mississippi drains three regions), weighting criteria accounted for materials received from storage facilities upstream of the region that would flow past several downstream population centers, as necessary. Table 3-64 lists the number of people using the public drinking water systems potentially affected by the degradation of radioactive materials.

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148090	American Trucking Associations v. EPA 1999	*American Trucking Associations v. U.S. Environmental Protection Agency,* No. 97-1440 (U.S. Court of Appeals for the District of Columbia Circuit). Decided May 14, 1999. TIC: 244121.
103071	ANS 1992	ANS (American Nuclear Society) 1992. *American National Standard for Determining Design Basis Flooding at Power Reactor Sites.* ANSI/ANS-2.8-1992. La Grange Park, Illinois: American Nuclear Society. TIC: 236034.
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102618	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Emergency Management Plan.* YMP/92-38, Rev. 3. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19980921.0373. In the Draft EIS, this reference was cited as DOE 1998k in Chapter 12.
104560	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Potential Rail Alignments.* YMP/98-104.0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990526.0034. In the Draft EIS, this reference was cited as DOE 1998f in Chapter 12.
104854	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Disturbances at Yucca Mountain Since June 21, 1991.* YMP-97-160.2. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990610.0319. In the Draft EIS, this reference was cited as DOE 1998h in Chapter 12.
153650	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Proposed Land Withdrawal Area.* YMP-98-200.0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20000926.0169.

154913	YMP 1998	YMP (Yucca Mountain Site Characterization Project) 1998. *Land Cover Types in the Proposed Land Withdrawal Area.* YMP-98-094.2. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. TIC: MOL.19990224.0274.
156763	YMP 2001	YMP (Yucca Mountain Site Characterization Project) 2001. "PETT and Tax Numbers." E-mail from Yucca Mountain Project to P. Baxter, June 26, 2001, with attachments. ACC: MOL.20010816.0151.

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4. ENVIRONMENTAL CONSEQUENCES OF REPOSITORY CONSTRUCTION, OPERATION AND MONITORING, AND CLOSURE

This chapter describes short-term environmental consequences that could result from the implementation of the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. *Short-term* refers to the period from the beginning of construction through final repository closure, and includes project phases of construction, operation and monitoring, and closure. For purposes of analysis, the repository would remain open from 115 to 341 years from the beginning of construction to final closure, depending upon the operating mode and operating parameters selected. Chapter 5 discusses the environmental consequences of long-term repository performance—that period out to 10,000 years and beyond after repository closure. Chapter 6 discusses the environmental consequences of transportation, and Chapter 7 discusses the environmental consequences of the No-Action Alternative.

Section 4.1 describes potential environmental impacts from required activities at the repository site to implement the Proposed Action, including continued site investigations (called *performance confirmation*), offsite manufacturing of repository components (for example, disposal containers and drip shields) and shipping casks, and a floodplain assessment. The implementation of the Proposed Action would require performance confirmation in support of a U.S. Nuclear Regulatory Commission licensing process. Section 4.2.1 describes potential environmental impacts of retrieval if such an option became necessary. Section 4.2.2 describes the environmental impacts associated with the receipt of waste prior to the start of emplacement.

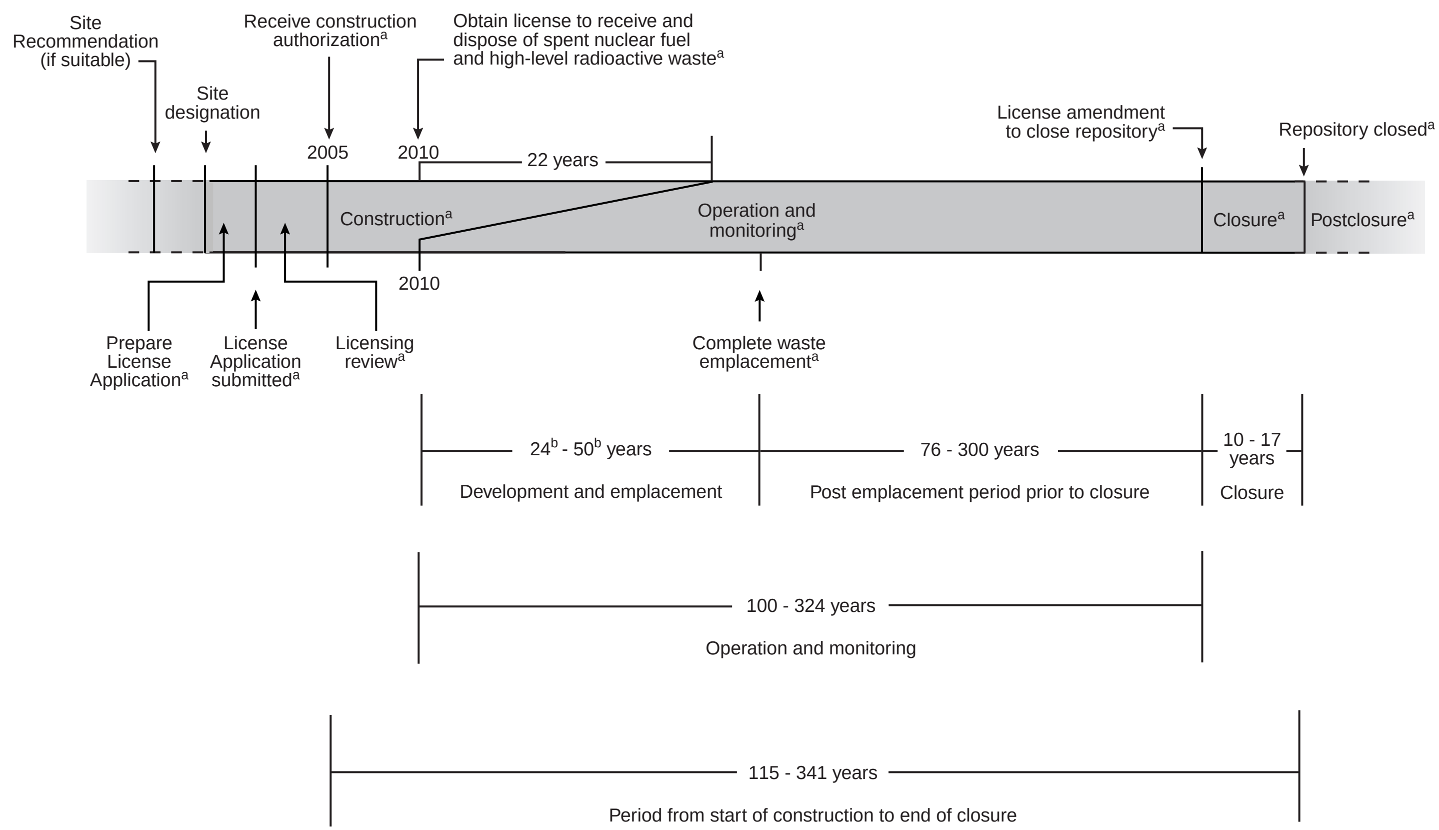
The U.S. Department of Energy (DOE) has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the Nuclear Waste Policy Act, as amended (NWPA), in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. This chapter contains information about short-term environmental impacts that would be directly associated with the construction, operation and monitoring, and eventual closure of a repository.

4.1 Short-Term Environmental Impacts of Performance Confirmation, Construction, Operation and Monitoring, and Closure of a Repository

This section describes the short-term environmental impacts associated with the Proposed Action. DOE has described the environmental impacts according to the phases of the Proposed Action—construction, operation and monitoring, and closure—and the activities (some of which overlap) associated with them. The following paragraphs summarize the phases and activities that would occur, and the operating modes evaluated in this environmental impact statement (EIS). Chapter 2 describes these operating modes in detail. Figure 4-1 shows the expected timeline for these phases. In addition, this section describes the impacts from the testing and performance confirmation activities that DOE would perform before the start of repository construction in support of a Nuclear Regulatory Commission licensing process. These activities, which would continue through repository closure, could require surface or subsurface excavations and drill holes, testing, and environmental monitoring. As these activities revealed more scientific data, DOE would expect their level of effort to decrease.

PRECONSTRUCTION TESTING AND PERFORMANCE CONFIRMATION ACTIVITIES

The preconstruction testing and performance confirmation program would continue many of the same types of activities performed during site characterization—tests, experiments, and analyses—for as long



a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 4-1. Monitored geologic repository range of milestones used for analysis.

as required. DOE would continue performance confirmation activities during all the phases of the repository project to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objective for the period after *permanent closure*.

INITIAL CONSTRUCTION PHASE (STARTING IN 2005, LASTING 5 YEARS)

The construction of facilities would begin when and if the Nuclear Regulatory Commission authorized DOE to build the repository. For analysis purposes, this EIS assumed construction would begin in about 2005. Site preparation, including the layout and grading of surface facility locations, would be part of the initial construction activities; DOE would construct new surface facilities or modify facilities built to support site characterization. Most surface facility construction would be completed during this phase, with the exception of the solar facility and aging pads, if built. Initial subsurface construction would excavate access mains, ventilation shafts, and the first emplacement drifts and prepare them for the start of emplacement activities, assumed for analysis purposes to begin in 2010. As mentioned above, performance testing and confirmation activities would be ongoing during this period.

OPERATION AND MONITORING PHASE

The operation and monitoring phase would last 100 to 324 years and would consist of an operations period and a monitoring period. The EIS analyses assumed that repository operations would begin in 2010, assuming DOE received a license from the Nuclear Regulatory Commission to receive and dispose of spent nuclear fuel and high-level radioactive waste. The operations period would include continued development (excavation and preparation for use) of the subsurface repository, receipt and handling of spent nuclear fuel and high-level waste in surface facilities, and emplacement of these materials in the completed portions of the subsurface repository. Development activities would last 22 years for all operating modes, concurrent with handling and emplacement. Handling and emplacement activities would last 24 years for the higher-temperature operating mode and for the lower-temperature operating mode if surface aging was not used. If surface aging was used, the operations period would last 50 years.

Monitoring of the emplaced material and maintenance of the repository would start with the first emplacement of waste packages and would continue through the closure phase. After the completion of emplacement, the monitoring period would begin, during which monitoring would be the primary activity. DOE would maintain the repository in a configuration that would enable continued monitoring and inspection of the waste packages, continued investigations in support of predictions of long-term repository performance (the ability to isolate waste from the accessible environment), and the retrieval of waste packages, if necessary. This period would last from 76 to 300 years. The first 3 years of the monitoring period would include the radioactive decontamination of surface facilities used for handling radioactive materials. Facilities would be decontaminated so there would be no chance for release of contamination when they were in standby mode during the monitoring period, and they would be ready for either demolition during the Closure Phase or for use as part of a retrieval contingency.

Future generations would need to decide whether to continue to maintain the repository in this open monitored condition or to close it. However, the Department expects that a repository could be maintained in an open monitored condition, with appropriate maintenance, for the time periods evaluated in this chapter. For this analysis, the EIS evaluates closure starting 100 years after the start of emplacement for the higher-temperature operating mode, and 149 to 324 years for the lower-temperature operating mode.

As mentioned above, DOE would continue its performance confirmation activities during the development, waste emplacement, and monitoring activities.

CLOSURE PHASE (LASTING 10 TO 17 YEARS)

Repository closure would occur after DOE applied for and received a license amendment from the Nuclear Regulatory Commission. Closure would take 10 years for the higher-temperature operating mode and from 11 to 17 years for the lower-temperature operating mode, depending on the operating parameters that had been employed. The closure of the repository facilities would include the following activities:

- Removing and salvaging valuable equipment and materials
- Backfilling the main drifts, access ramps, ventilation shafts, and connecting openings and sealing underground-to-surface openings
- Constructing monuments to mark the area
- Decommissioning and demolishing surface facilities
- Restoring the surface to its approximate condition before repository construction
- Continuing performance confirmation activities as necessary

REPOSITORY OPERATING MODES

As discussed in Chapter 2, the repository design is conceptual and continues to evolve. This evolution will continue throughout the process established by the Nuclear Regulatory Commission for license application and construction authorization. To present the range of short-term environmental impacts that could occur, DOE has selected a range of higher-temperature to lower-temperature operating modes for evaluation in this EIS. The higher-temperature operating mode has an established set of operating parameters (DIRS 153849-DOE 2001, all). The desired characteristics for a lower-temperature operating mode could be reached under a variety of operating parameters, and was evaluated using a range of parameter values affecting repository size and ventilation characteristics, number and spacing of waste packages, and length of activity periods. Elsewhere in this EIS (Chapter 6 and Appendix J) the potential impacts of specific transportation and fuel packaging options (Appendix F) are examined. Where transportation and spent fuel packaging options may make a difference in repository impact analysis, legal-weight truck transportation option and/or uncanistered spent fuel packaging have been assumed because they typically result in the highest potential impacts. There are a few exceptions to this general rule, for example, where use of canisters for fuel packaging would result in additional waste. These instances are specifically identified where they occur in Chapter 4.

4.1.1 IMPACTS TO LAND USE AND OWNERSHIP

This section describes potential land-use and ownership impacts from the preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. DOE determined that information useful in an evaluation of land-use and ownership impacts should identify the current ownership of the land that repository-related activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts is a land withdrawal area that DOE used for the EIS analysis. Congress would have to define the actual land withdrawal area. The analysis considered impacts from direct disturbances related to repository construction and operation. It also considered impacts from the transfer of lands to DOE control.

4.1.1.1 Impacts to Land Use and Ownership During Preconstruction Testing and Performance Confirmation and from Land Withdrawal

Preconstruction testing and performance confirmation activities would occur primarily on land managed by the Federal Government. As with site characterization, these activities would occur in the land withdrawal area that DOE analyzed in the EIS (see Section 3.1.1). DOE would seek to maintain the current administrative land withdrawal of 20 square kilometers (7.7 square miles), current right-of-way reservations N-47748 [210 square kilometers (81 square miles)] and N-48602 [about 75 square kilometers (29 square miles)], and the existing management agreement between the Yucca Mountain Site Characterization Office and the Nevada Operations Office (as described in Section 3.1.1) until Congress approved a permanent land withdrawal. The Nevada Operations Office operates the Nevada Test Site.

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of the land surrounding the repository site. The Department believes that an area of approximately 600 square kilometers (230 square miles) on Bureau of Land Management, U.S. Air Force, and DOE lands in southern Nevada would be sufficient (see Section 3.1). Of the 600 square kilometers, approximately 210 square kilometers (81 square miles) comprise the right-of-way reservation noted above, with 180 square kilometers (70 square miles) remaining in public lands under the Bureau of Land Management's right-of-way agreement with DOE. As such, these lands are currently available for public use including mineral exploration and recreation. There are several current mining and mineral claims within the parcel that would be affected by withdrawal from public use. Such leases and unpatented mining claims could be withdrawn by the Bureau of Land Management or could be voided by an act of Congress that would withdraw the land for a repository. The current recreational use of the land under the Bureau of Land Management's right-of-way agreement could also be withdrawn by the Bureau or by establishment by Congress of a repository at Yucca Mountain.

Nuclear Regulatory Commission licensing conditions for a repository (10 CFR 60.121) include a requirement that DOE either own or have permanent control of the lands for which it is seeking a repository license. As noted above, portions of the area proposed for the repository are lands controlled by the Bureau of Land Management, the Air Force, and the DOE Nevada Operations Office.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. Nuclear Regulatory Commission regulations require that repository operations areas and postclosure controlled areas be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise. If Congress approved withdrawal of lands for repository purposes, any other use of those lands would be subject to conditions of the withdrawal.

Repository construction, operation and monitoring, and closure activities would require the active use of a maximum of about 6 square kilometers (1,500 acres, 2.3 square miles) composed of small noncontiguous areas within the larger 600-square-kilometer (230-square-mile) land withdrawal area used for purposes of analysis.

Chapter 2 describes activities that DOE would conduct in the Yucca Mountain site active-use area and the land withdrawal area.

The amount of land that DOE would need to support repository activities would vary little among repository operating modes. Most of the surface facilities and disturbed land would be in the South

Portal Development Area and North Portal Operations Area. Repository activities would not conflict with current land uses on adjacent Bureau of Land Management, Air Force, or Nevada Test Site lands.

4.1.1.2 Impacts to Land Use and Ownership from Construction, Operation and Monitoring, and Closure

During the construction and operation and monitoring phases, DOE would disturb or clear land for the repository and surface facility construction. The Department would use this land for surface facilities, performance confirmation activities, and excavated rock storage. DOE does not expect conflicts with uses on surrounding lands because repository operations would occur in a confined, secure area over which DOE would have permanent control. Furthermore, this is public land, much of which has been used for repository site characterization for nearly two decades.

As described in Section 4.1, surface activities associated with closure would include constructing monuments, decommissioning and decontaminating facilities, and restoring the surface to its approximate preconstruction condition. DOE could use material from the excavated rock pile to backfill the repository tunnels (excluding the emplacement drifts), and would contour the excavated material remaining after backfill and subsurface closure activities and cover it with topsoil. During closure, the Department would restore disturbed areas to their approximate condition before repository construction.

Surface disturbance for the higher-temperature operating mode would be 4.3 square kilometers (1,000 acres). Surface disturbance for the lower-temperature operating mode would range from 4.5 square kilometers (1,100 acres) to approximately 6 square kilometers (1,500 acres). The surface disturbance represents a small amount of the 600 square kilometers (150,000 acres) of land withdrawn for the repository. Therefore, there would be small impacts to land use due to the implementation of the Proposed Action.

4.1.2 IMPACTS TO AIR QUALITY

This section describes possible nonradiological and radiological impacts to air quality from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure. Appendix G provides more details on the methods used for air quality analysis.

Sources of nonradiological air pollutants at the proposed repository site would include fugitive dust emissions from land disturbances and excavated rock handling; nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter emissions from fossil fuel consumption; and fugitive dust emissions from concrete batch plant operations. DOE used the Industrial Source Complex computer program to estimate annual and short-term (24-hour or less) nonradiological air quality impacts (DIRS 103242-EPA 1995, all). Nonradiological impacts evaluated include those from four criteria pollutants: nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter with an aerodynamic diameter of 10 micrometers or less (PM_{10}). In addition, potential impacts were evaluated for the possibly harmful mineral cristobalite, a form of silica dust that is the causative agent for silicosis and might be a carcinogen. The analysis did not quantitatively address the two other criteria pollutants, lead and ozone (see Appendix G, Section G.1). There would be no sources of airborne lead at the repository, and very small sources of volatile organic carbon compounds, which are ozone precursors. The analysis did make a general comparison to the pending National Ambient Air Quality Standard for particulate matter with an aerodynamic diameter of 2.5 micrometers or less ($PM_{2.5}$), which has yet to be implemented (see Chapter 3, Section 3.1.2.1). DOE used these standards, among other air quality standards shown in Chapter 3, Section 3.1.2.1, in analyzing the nonradiological air quality impacts discussed in this section.

Radiological air quality impacts could occur from releases of radionuclides, primarily naturally occurring radon-222 and its radioactive decay products, from the rock into the subsurface facility and then into the ventilation air during all phases of the repository project. Radioactive noble gases, principally krypton-85, would be released from surface facilities during the handling of spent nuclear fuel. DOE used dose factors from DIRS 101882-NCRP (1996, Volume 1, pp. 113 and 125) to estimate doses to *noninvolved workers* (workers who could be exposed to air emissions from repository activities but who would not be directly associated with those activities) and offsite individuals from such releases.

The air quality analysis evaluated nonradiological air quality impacts at the potential locations of maximally exposed members of the public. It estimated radiological air quality impacts as the doses to maximally exposed individuals and populations of the public and to noninvolved workers. The analysis did not consider involved workers because they would be exposed in the workplace, as discussed in Section 4.1.7. Overall, the impacts to regional air quality from performance confirmation, repository construction, operation and monitoring, and closure would be small. Exposures of maximally exposed individuals to airborne pollutants would be a small fraction of applicable regulatory limits. For periods of 1 year or longer, maximally exposed individuals were assumed to be at the southern boundary of the land withdrawal area, the closest location they would be for long periods during repository activities.

4.1.2.1 Impacts to Air Quality from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would generate particulate and gaseous emissions. Particulates would be generated by drilling, blasting, rock removal and storage, batch concrete plant operation, surface grading and leveling, wind erosion, and vehicle travel on paved and unpaved roads. Gaseous air pollutant emissions would consist of carbon monoxide, *nitrogen oxides*, *sulfur oxides*, and hydrocarbons. These pollutants would be produced by diesel- and gasoline-powered construction equipment and motor vehicles and by diesel-powered drilling engines and electric generators.

Air quality measurements at the repository site and in the repository site vicinity (see Section 3.1.2) have shown that site characterization activities similar to those described above have had a very small impact on the concentration levels of PM_{10} and of gaseous pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone). This analysis assumed that site characterization activities are representative of preconstruction testing and performance confirmation activities. As described in Section 3.1.2, pollutant levels have been below applicable National Ambient Air Quality Standards. Based on this experience, DOE does not expect large impacts to air quality from preconstruction testing and performance confirmation activities.

4.1.2.2 Impacts to Air Quality from Construction

This section describes potential radiological and nonradiological air quality impacts during the initial construction of the Yucca Mountain Repository, which for analysis purposes would last 5 years, from 2005 to 2010. Activities during this phase would include subsurface excavation to prepare the repository for initial emplacement operations and construction of surface facilities at the North Portal Operations Area, South Portal Development Area, and ventilation shaft areas and associated access roads.

4.1.2.2.1 *Nonradiological Impacts to Air Quality from Construction*

During the initial construction, repository activities would result in emissions of air pollutants. Subsurface excavation would release dust (particulate matter) from the ventilation exhaust. The excavation of rock would generate dust in the drifts. The dust would be vented from the subsurface through the South Portal. Construction activities on the surface would result in the following air emissions:

- Fugitive dust from the placement and maintenance of excavated rock at a surface storage site

- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, etc.) and particulate matter from the operation of construction vehicles
- Gaseous criteria pollutants and particulate matter from a diesel-fueled boiler at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust from land-disturbing activities on the surface during construction activities

Table 4-1 lists the maximum estimated impacts to air quality at the boundary of the land withdrawal area used for purposes of analysis in this EIS. As listed in this table, maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small. Criteria pollutant concentrations would be less than 2 percent of the applicable regulatory limits for all operating modes with the exception of PM_{10}. The 24-hour PM_{10} concentrations for the range of operating modes would be about 4 to 6 percent of the regulatory limit. In addition, DOE expects levels of $PM_{2.5}$ to be well below the applicable standard because a large fraction of the particulates for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not have a major effect on concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-1. Maximum construction phase concentrations of criteria pollutants and cristobalite at the land withdrawal area boundary (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.40	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.042 - 0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.69	0.74 - 0.94	1.4	1.5 - 1.9
	24-hour	150 (65)	6.5	7.0 - 8.4	4.3	4.7 - 5.6
Cristobalite	[Annual[d]]	[10[d]]	0.018	0.017 - 0.018	0.18	0.17 - 0.18

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Emissions of nitrogen dioxide, sulfur dioxide, and carbon monoxide would not be greatly different under the higher- and lower-temperature operating modes during the construction phase. Differences do result for PM_{10} releases during the larger land disturbances and maintenance of the larger excavated rock piles of the lower-temperature operating modes. The construction of ventilation shafts and their access roads contributes significantly to the particulate releases. Although well within regulatory limits, particulate release rates would be further reduced by dust suppression measures taken during construction.

Cristobalite is one of several naturally occurring crystalline forms of silica (silicon dioxide) that occur in Yucca Mountain tuffs. Cristobalite is principally a concern for involved workers who could inhale it during subsurface excavation operations (see Section 4.1.7). Prolonged high exposure to crystalline silica might cause silicosis, a disease characterized by scarring of lung tissue. Research has shown an increased cancer risk to humans who already have developed adverse noncancer effects from silicosis, but the cancer risk to otherwise healthy individuals is not clear (DIRS 103243-EPA 1996, p. 1-5). The evaluation of exposure to cristobalite encompassed potential impacts from exposure to other forms of crystalline silica, including quartz and tridymite, that occur at Yucca Mountain. See Appendix F, Section F.1.2, for more information.

Cristobalite would be emitted from the subsurface in exhaust ventilation air during excavation operations and would be released as fugitive dust from the excavated rock pile, so members of the public and noninvolved workers could be exposed. Fugitive dust from the excavated rock pile would be the largest potential source of cristobalite exposure to the public. The analysis assumed that 28 percent of the fugitive dust released from this pile and from subsurface excavation would be cristobalite, reflecting the cristobalite content of the parent rock, which ranges from 18 to 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81). Using the parent rock percentage probably overestimates the airborne cristobalite concentration because studies of both ambient and occupational airborne crystalline silica have shown that most is coarse and not respirable, and that larger particles rapidly deposit on the surface (DIRS 103243-EPA 1996, p. 3-26). Table 4-1 lists estimated cristobalite concentrations at the analyzed land withdrawal area boundary during the construction phase.

There are no regulatory limits for public exposure to cristobalite. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Over a 70-year lifetime, this cumulative exposure benchmark would correspond to an annual average exposure concentration of about 14 micrograms per cubic meter. For added conservatism, this analysis used an annual concentration of 10 micrograms per cubic meter as the benchmark for comparison. The postulated annual average exposure of the hypothetical maximally exposed member of the public to cristobalite from construction activities would be small, about 0.02 microgram per cubic meter or less for the various operating modes, or less than 0.2 (0.18) percent of the benchmark. DOE would use common dust suppression techniques (water spraying, etc.) to further reduce releases of fugitive dust, and hence cristobalite, from the excavated rock pile.

4.1.2.2.2 *Radiological Impacts to Air Quality from Construction*

No releases of manmade radionuclides would occur during the construction phase because such materials would not be present until the repository began operations. However, the air exhausted from the subsurface would contain naturally occurring radon-222 and its radioactive decay products. (Further references to radon in this discussion include its radioactive decay products.) Radon-222 is a noble gas and decay product of uranium-238 that occurs naturally in the rock. Exposure to radon-222 is ubiquitous (that is, it occurs everywhere). As described in Chapter 3, Section 3.1.8, exposure to naturally occurring radon-222 results in an annual average individual dose in the United States of about 200 millirem. In the subsurface, radon-222 would leave the rock and enter the drifts, a process called radon emanation. Once in the repository drifts the radon and decay products would be exhausted as part of repository ventilation. DOE based potential future releases of radon-222 on modeled estimates of radon flux, concentration, and release in the repository (DIRS 154176-CRWMS M&O 2000, all). These estimates were generated using observed radon concentrations in the Exploratory Studies Facility (DIRS 150246-CRWMS M&O 2000, Attachment X) and considering the repository structure and ventilation characteristics, particularly the ventilation pressure differentials. Total estimated radon releases during the 5-year construction phase would be very similar for the range of repository operating modes. These releases, and the potential doses that resulted from them, would be similar because the size and structure of the excavated repository and the repository ventilation would be similar under each mode during the construction phase. Appendix G, Section G.2, describes the methods, procedures, and basis of analysis.

The dose to the offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be about 1.7 to 2.0 millirem for the 5-year initial construction phase under the flexible design repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be no more than about 0.53 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3.5 percent of this standard. The offsite population dose would be 33 to 40 person-rem. The maximum annual dose to the maximally exposed noninvolved repository worker would be about 1.9 to 2.3 millirem during the initial construction phase. The analysis assumed that this worker, while at the site, would be in an office about 100 meters (330 feet) from the South Portal. The noninvolved worker population exposed to radon-222 from exhaust ventilation would include all the repository workers on the surface. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal, would receive most of the population dose. The dose to the noninvolved worker population from the air *pathway* would be less than 0.5 (0.48) person-rem during this phase (see Appendix G, Section G.2).

Table 4-2 lists estimated annual and 5-year construction phase doses from radon-222 for the maximally exposed individuals (both public and noninvolved surface worker) and potentially affected populations from the air pathway. Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-2. Radiation doses to maximally exposed individuals and populations during initial construction phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual	Total	Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	1.7	0.43	1.7 - 2.0	0.43 - 0.53
80-kilometer population[d] (person-rem)	33	8.4	33 - 40	8.4 - 10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	7.5	2.0	7.5 - 9.0	1.9 - 2.3
Yucca Mountain noninvolved worker population[f] (person-rem)	0.41	0.10	0.41 - 0.48	0.10 - 0.13
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0013	0.00032	0.0013 - 0.0015	0.00032 - 0.00039

a. Numbers are rounded to two significant figures.
b. Annual values are for the maximum year during the construction phase.
c. MEI = maximally exposed individual; public MEI location would be at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. The maximally exposed noninvolved worker location would be in the South Portal Development Area.
f. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.3 Impacts to Air Quality from Operation and Monitoring

This section describes potential nonradiological and radiological air quality impacts from routine operation and monitoring at the Yucca Mountain Repository. For analysis purposes, this phase would begin in 2010 for both repository operating modes; it would last for 100 years for the higher-temperature operating mode and from 149 to 324 years for the lower-temperature operating mode. Activities during this phase would include the continued excavation of subsurface drifts (beginning in 2010 and lasting 22 years), the receipt and packaging (handling) of spent nuclear fuel and high-level radioactive waste at the North Portal surface facilities (beginning in 2010 and lasting 24 years), and the emplacement of disposal containers in the repository (beginning in 2010 and lasting 24 years without aging or 50 years with aging). These activities would take place concurrently. After the emplacement of all spent nuclear fuel, monitoring of the disposal containers and maintenance of repository facilities would last from 76 to 300 years.

4.1.2.3.1 *Nonradiological Impacts to Air Quality from Operation and Monitoring*

DOE evaluated nonradiological air quality impacts from activities beginning at 2010, when handling and continued subsurface development and emplacement activities would occur simultaneously. This phase could last from 100 to 324 years, depending on the operating mode and design. Continued development of the subsurface facilities would last 22 years for all operating modes. Continued subsurface development would result in the release of dust (particulate matter) from the ventilation exhaust (at the South Portal). Activities on the surface would result in the following air emissions during this period:

- Fugitive dust emissions from the excavation, placement, and maintenance of rock at a surface storage pile
- Fugitive dust emissions from continued construction of the aging pads, if used to achieve lower-temperature operations
- Gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide) and particulate matter from vehicle operation during construction and emplacement
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Cristobalite emissions from subsurface excavations and the excavated rock storage pile

The level of emissions would vary among the operating modes. The lower-temperature operating mode would result in larger excavated rock piles on the surface, which in turn would result in larger fugitive dust emissions and necessitate larger vehicle fleets for operation and maintenance.

Table 4-3 lists estimated maximum concentrations at the land withdrawal area boundary for the higher- and lower-temperature operating modes.

As listed in Table 4-3, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be very small. For the range of operating modes, the public maximally exposed individual would be exposed to less than 2 (1.6) percent of the applicable regulatory limits. In addition, levels of $PM_{2.5}$ should be well below the applicable standard because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. The concentrations of $PM_{2.5}$ would not be as affected by these suppression measures because fugitive dust is not a major source of $PM_{2.5}$.

Table 4-3 also lists cristobalite concentrations at the land withdrawal area boundary. As discussed for the initial construction phase (see Section 4.1.2.2.1), the analysis of the continuing construction, operation, and monitoring period assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. There are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The

Table 4-3. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during the operation and monitoring phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.28	0.28 - 0.31	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.089 - 0.092	0.11	0.11 - 0.12
	24-hour	365	1.2	1.2	0.33	0.34
	3-hour	1,300	7.8	7.9 - 8.0	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.7	2.7 - 3.0	0.026	0.027 - 0.029
	1-hour	40,000	19	19 - 21	0.048	0.049 - 0.052
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.080	0.10 - 0.19	0.16	0.20 - 0.39
	24-hour	150 (65)	0.97	1.3 - 2.3	0.65	0.87 - 1.6
Cristobalite	Annual[d]	10[d]	0.0093	0.009 - 0.017	0.093	0.091 - 0.17

a. All numbers except regulatory limits are rounded to two significant figures.

b. Regulatory limits for criteria pollutants are from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).

c. Sum of highest concentrations at the accessible land withdrawal boundary regardless of direction. See Appendix G, Section G.1, for additional information.

d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

estimated exposures to cristobalite from repository operations would be small, about 0.017 microgram per cubic meter or less for the range of operating modes, or less than 0.2 (0.17) percent of the benchmark.

Concentrations would differ between the construction phase and the emplacement and development activities. The rate of fugitive dust release and the subsequent PM_{10} concentrations would be higher during the construction phase than during emplacement and development activities because of the differing amount of land surface disturbance. Concentrations of cristobalite would be comparable in the construction and operation and monitoring phases. Concentrations of gaseous criteria pollutants would decrease during emplacement and development activities because vehicle emissions would decrease during emplacement and development. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

After the completion of emplacement activities, DOE would continue monitoring and maintenance activities lasting 76 to 300 years at the repository until closure. During this period, air pollutant emissions would decrease. Subsurface excavation and handling activities would be complete, resulting in a lower level of emissions. Pollutant concentrations at the land withdrawal area boundary, therefore, would be lower than those listed in Table 4-3.

The flexible design repository operating modes would remove at least 70 percent of the heat generated by the spent nuclear fuel inventory during the preclosure period (DIRS 153849-DOE 2001, p. 2-15). The peak ventilation air temperature for the higher-temperature operating mode would be 58ºC (136ºF) for 1.4-kilowatt-per-meter linear thermal load, occurring 10 years into the preclosure period and decreasing thereafter (DIRS 150941-CRWMS M&O 2000, pp. 4-24 to 4-25). The higher-temperature operating mode has the highest linear thermal load (DIRS 153849-DOE 2001, p. 2-24) and would have the highest exhaust air temperatures. This air temperature would be lower than the exhaust air temperature of many other industrial processes such as powerplants, manufacturing facilities, and incinerators. Impacts from the heat released in ventilation air would be unlikely on either the climate or ecosystems of the area.

4.1.2.3.2 *Radiological Impacts to Air Quality from Operation and Monitoring*

The handling of spent nuclear fuel and continued subsurface ventilation would result in radionuclide releases during the early years of the operation and monitoring phase. Radionuclides would be released during transfer of fuel assemblies from transportation casks to disposal containers. Releases of naturally occurring radon-222 from subsurface ventilation would continue. If surface aging was used, the initial 24 years of operations would be followed by 26 years of emplacing commercial spent nuclear fuel from the aging facility. Aging would result in a 50-year operations period rather than the 24-year period without aging.

After the completion of handling and emplacement operations, DOE would continue monitoring repository facility maintenance activities for 76 to 300 years. During this period, the Department would continue to ventilate the subsurface. Releases of naturally occurring radon-222 from subsurface ventilation would continue.

Operations Period. The main radionuclide released to the atmosphere from the handling of spent nuclear fuel assemblies in the Waste Handling Building would be krypton-85, a radioactive noble gas (DIRS 101893-NRC 1979, p. 4-10). Approximately 2,600 curies would be released annually (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of other noble gas radionuclides would be very small. Estimated annual releases would be about 1.0×10^{-6} curie of krypton-81, 3.3×10^{-5} curie of radon-219, 5.9×10^{-2} curie of radon-220, and 4.6×10^{-6} curie of radon-222 (DIRS 152010-CRWMS M&O 2000, p. 52). Releases of these radionuclides, which are noble gases, would not be affected by facility filtration systems. No releases of particulate or soluble radionuclides would be likely. These radionuclides would be captured in the water of the transfer pool or the Waste Handling Building air filtration system.

A continuing source of dose to members of the public and noninvolved (surface) workers would be releases of naturally occurring radon-222 from the subsurface. Estimated radon emissions during the continuing construction, operation, and monitoring period would be greater than those during the initial construction period because of the larger repository size, with more surface area for radon flux from the repository walls and greater quantities exhausted by ventilation. The effect of waste packages heating the walls of the emplacement drifts, which would slightly increase the radon flux, was also considered (DIRS 154176-CRWMS M&O 2000, p. 10). The estimated differences in radon releases would be a function primarily of the waste package spacing, which would affect the total repository size, and of the duration of the monitoring period. In general, a larger waste package spacing distance would lead to a larger repository, which would result in more radon released per year and a shorter ventilation period. Annual releases, therefore, would be higher but total releases would be lower. Appendix G, Section G.2.3.1, contains more information on estimates of radon release for the range of operating modes. Activation of the air around waste packages would result in the creation of a small quantity of radioactive noble gases. These noble gases would contribute negligibly to the dose from the air pathway (DIRS 139546-CRWMS M&O 2000, all).

Table 4-4 lists estimated annual doses and doses during the handling and emplacement period to the maximally exposed individuals (public and noninvolved worker) and potentially affected populations from radionuclide releases from surface and subsurface facilities. As for the other project phases, naturally occurring radon-222 and its decay products released in subsurface ventilation air would be the major dose contributors from airborne releases. Krypton-85 and the other noble gas radionuclides released from the surface facilities would be a small component of the overall dose, contributing less than 0.01 percent of the dose to the public and typically less than 1 percent of the dose to noninvolved workers for the operations period. The principal exception would be the dose to the noninvolved worker population at the Nevada Test Site, where the krypton-85 contribution to dose would be as high as 3.5 percent of the total dose. Appendix G, Section G.2.3.2, discusses the methods for calculating the doses, and Section 4.1.7 discusses potential human health impacts from these doses.

Table 4-4. Radiation doses for maximally exposed individuals and populations during the operations period.[a,b]

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
Offsite MEI[d] (millirem)	12	0.73	17 - 43	1.0 - 1.3
80-kilometer population[e] (person-rem)	230	14	320 - 830	20 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[f] (millirem)	30	2.0	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker population[g] (person-rem)	1.2	0.081	1.8 - 1.9	0.12 - 0.13
Nevada Test Site noninvolved worker population[h] (person-rem)	0.011	0.00063	0.015 - 0.043	0.00090 - 0.0012

a. Numbers are rounded to two significant figures.
b. Fuel handling activities would last 24 years. Emplacement activities would last 24 years with no aging or 50 years with aging. Continuing subsurface development activities would last 22 years.
c. Maximum annual dose would occur during the last year of development, when the repository had reached its largest and DOE still used the South Portal for exhaust ventilation.
d. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker location would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

The dose to the offsite maximally exposed individual would be 12 to 20 millirem during the 24 years of operations, increasing to 43 millirem for the additional 26 years of operations if DOE used aging. The maximum annual dose to the offsite maximally exposed individual would be about 0.73 to 1.3 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 5 to 9 percent of this standard. The population dose would be 230 to 390 person-rem for 24 years of operations, increasing to 830 person-rem for the additional 26 years of operations with aging. Essentially the entire dose would be from naturally occurring radon-222 released from the subsurface in ventilation air. Releases of radioactive noble gases from surface facilities (Waste Handling and Waste Treatment Buildings) during spent nuclear fuel handling would make very small differences in the dose received. Aging would increase the operations period by 26 years, but also would decrease the monitoring period by 26 years, so the total impact would be unchanged.

The dose to the maximally exposed noninvolved (surface) worker in an office about 100 meters (330 feet) from the South Portal would be about 30 to 42 millirem during the 24 years of handling and emplacement activities, increasing less than 0.2 millirem for the additional 26 years of operations for aging. The increase would be small because DOE would stop using the South Portal for exhaust ventilation at the completion of development, and exhaust from the ventilation shafts would result in much less dose to the maximally exposed worker. The dose to the noninvolved worker population would vary in proportion to (1) the amount of radon-222 released from the subsurface, because radon-222 would dominate the radiation doses, and (2) the number of noninvolved (surface) workers. At the North Portal Operations Area, there would be about 1,300 workers annually (a total of 31,000 to 32,000 worker-years for 24 years of operations). This total would increase to about 50,000 surface worker-years for the 50 years of operations needed for aging. In addition, an estimated 1,500 to 2,100 total subsurface worker-years would be needed on the surface at the South Portal Development Area (see Appendix G, Table G-49). The noninvolved worker population dose would range from 1.2 to 1.8 person-rem over the 24-year emplacement period, increasing slightly to 1.9 person-rem considering the additional 26 years of the operations period needed for aging. Workers at the South Portal Development Area, who would be near the ground-level releases of radon from this portal during development activities, would receive most of the population dose from airborne releases. However, the bulk of worker radiation dose comes not from airborne releases but from more direct occupational exposure. Section 4.1.7 discusses impacts to workers directly involved in handling, emplacement, and continuing development activities.

Monitoring Period. Monitoring would continue and maintenance would begin immediately after the completion of emplacement activities. One of the first activities would be the decontamination of the surface material handling facilities. This activity, which would last 3 years, would require a larger number of noninvolved workers. These workers would be exposed to naturally occurring radon ventilated from the subsurface. Decontamination of the surface facilities would result in no or negligible airborne releases of radionuclides because of the low levels of contamination present, high-efficiency particulate air filters on the air exhausts, and modern facility design and decontamination techniques that would minimize the potential for airborne contamination. After the completion of decontamination, most of the noninvolved workers would no longer be employed, resulting in a much lower noninvolved worker population and correspondingly lower worker population dose.

Monitoring periods would range from 76 to 300 years depending on the repository operating mode and selected operating parameters. Table 4-5 lists estimated maximum annual doses and total doses that would occur from monitoring and maintenance activities to maximally exposed individuals and potentially affected populations from subsurface radon releases. Section 4.1.7 discusses potential radiological impacts from these doses. The dose over the 70-year lifetime of the hypothetical offsite maximally exposed individual, at the southern boundary of the land withdrawal area, would be 29 to 62 millirem during monitoring and maintenance activities for the range of repository operating modes. The maximum annual dose to the offsite maximally exposed individual would be about 0.41 to 0.89 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The hypothetical offsite maximally exposed individual would receive a higher dose than the noninvolved worker maximally exposed individual because air would be removed from the repository through exhaust shafts, which would result in more radon being carried to the exposure point for the offsite individual than to that for the noninvolved worker.

The population dose for monitoring and maintenance activities would range from 600 to 3,500 person-rem, the difference mainly reflecting the range of 76 to 300 years of postemplacement monitoring. The dose to the maximally exposed noninvolved (surface) worker, who would be at the South Portal Development Area, would range from 0.096 to 0.33 millirem for a 50-year working lifetime during monitoring and maintenance activities. The dose to the repository noninvolved (surface) worker population, which would include all surface workers (most of whom would be at the North Portal Operations Area), would range from 0.0091 to 0.05 person-rem for the monitoring period.

In general, longer periods of monitoring and maintenance activities would result in larger total releases of radon and its decay products and potentially extend these impacts to future generations of workers and the public. Highest total doses during the monitoring period for the 80-kilometer (50-mile) population and the Nevada Test Site noninvolved worker population would be under conditions of maximum ventilation and moderate waste package spacing, which would require the longest time (300 years) of ventilation and monitoring. For the other potential doses listed in Table 4-5, the highest potential total and annual doses for monitoring would be under conditions of largest waste package spacing, which would require the largest repository and have the largest radon release per year from the repository. Section 4.1.7 discusses human health impacts to the public and workers from the monitoring period.

Table 4-5. Radiation doses to maximally exposed individuals and populations during the monitoring period.[a,b]

Impact	Operating mode: Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Maximum annual
Dose to public				
Offsite MEI[c] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population[d] (person-rem)	600	8	1,500 - 3,500	11 - 17
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.096	0.0019	0.16 - 0.33	0.0011 - 0.0067
Yucca Mountain noninvolved worker population (person-rem)	0.0091	0.0013[f]	0.031 - 0.05	0.000034 - 0.0057[f]
Nevada Test Site noninvolved worker population[g] (person-rem)	0.033	0.00044	0.083 - 0.19	0.00021 - 0.00094

a. Numbers are rounded to two significant figures.
b. Decontamination of surface facilities during the operation and monitoring phase would last 3 years at the beginning of monitoring, which would last from 76 to 300 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area. Values are for a 70-year lifetime.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area. Values are for a 50-year onsite working lifetime.
f. Maximum annual dose occurs during the 3 years of decontamination activities when worker population is largest.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.4 Impacts to Air Quality from Closure

This section describes potential nonradiological and radiological air quality impacts during the closure phase of the proposed Yucca Mountain Repository, which would begin after the 76 to 300 years of monitoring and last 10 to 17 years. Activities during this phase would include the closure of subsurface repository facilities, the decommissioning of surface facilities, and the reclamation of remaining disturbed lands.

4.1.2.4.1 *Nonradiological Impacts to Air Quality from Closure*

During the closure phase, nonradiological air emissions would result from the backfilling and sealing of the repository subsurface and the reclamation of disturbed surface lands. Air emission sources would include the following:

- Fugitive dust emissions from the handling, processing, and transfer of backfill material to the subsurface
- Releases of gaseous criteria pollutants (nitrogen dioxide, sulfur dioxide, and carbon monoxide) and particulate matter from fuel consumption
- Gaseous criteria pollutants and particulate matter from diesel-fed boilers at the North Portal Operations Area
- Particulate matter from a concrete batch plant at the North Portal Operations Area
- Fugitive dust releases from demolishing buildings, removing debris, and reclaiming land

- Cristobalite releases associated with handling and storing excavated rock

Table 4-6 lists potential impacts at the location of the offsite maximally exposed individual from the closure of the repository for the higher- and lower-temperature operating modes.

Table 4-6. Maximum criteria pollutant and cristobalite concentrations at the land withdrawal area boundary during closure phase (micrograms per cubic meter).[a]

			Operating mode			
			Maximum concentration[c]		Percent of regulatory limit	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.54	0.54	0.54	0.54 - 0.55
Sulfur dioxide	Annual	80	0.11	0.11	0.15	0.15
	24-hour	365	1.4	1.4	0.38	0.38
	3-hour	1,300	9.3	9.3	0.71	0.71 - 0.72
Carbon monoxide	8-hour	10,000	4.7	4.7	0.045	0.045 - 0.046
	1-hour	40,000	31	31	0.078	0.078
PM_{10} ($PM_{2.5}$)	Annual	50 (15)	0.38	0.34 - 0.37	0.76	0.67 - 0.73
	24-hour	150 (65)	5.5	5.2 - 5.4	3.7	3.4 - 3.6
Cristobalite	Annual[d]	10[d]	0.012	0.0089 - 0.0098	0.12	0.089 - 0.098

a. All numbers except regulatory limits are rounded to two significant figures.
b. Regulatory limits from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Table 3-5).
c. Sum of the highest concentrations at the accessible land withdrawal boundary regardless of direction.
d. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, p. 1-5) states that the risk of silicosis is less than 1 percent for a cumulative exposure of 1,000 (micrograms per cubic meter) × years. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Gaseous criteria pollutants would result primarily from vehicle exhaust. During the closure phase, the maximum offsite concentrations of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} would be small, with the gaseous criteria pollutant concentrations being less than 1 percent of the applicable regulatory limits. The 24-hour PM_{10} concentrations would be about 4 percent of the regulatory limit for all operating modes. Levels of $PM_{2.5}$ should also be well below the applicable standard, because a large fraction of the particulates listed for PM_{10} would be larger than 2.5 micrometers. The analysis did not consider standard construction dust suppression measures, which DOE would implement and which would further lower projected PM_{10} concentrations by reducing fugitive dust from surface-disturbing activities. These measures would not affect the concentrations of $PM_{2.5}$ because fugitive dust is not a major source of $PM_{2.5}$.

As discussed for the construction phase (see Section 4.1.2.2.1), the analysis of the closure phase assumed that 28 percent of the fugitive dust released from the excavated rock pile would be cristobalite. Table 4-6 lists estimated cristobalite concentrations to which the offsite maximally exposed individual would be exposed during closure. As noted in Section 4.1.2.2.1, there are no public limits for exposure to cristobalite, so the analysis used an approximate annual average concentration of 10 micrograms per cubic meter as a benchmark. The postulated exposure to cristobalite from closure activities would be small, about 0.01 microgram per cubic meter or less for all three thermal load scenarios, or less than one-tenth of 1 percent (0.098) of the benchmark. For all pollutants, the slight differences in estimated concentrations do not provide meaningful distinctions among the operating modes.

4.1.2.4.2 *Radiological Impacts to Air Quality from Closure*

During the closure phase the only doses from releases of radionuclides to the atmosphere would be from naturally occurring radon-222 and its radioactive decay products released from the continued ventilation of subsurface facilities. The analysis assumed that subsurface ventilation would continue for the duration of the closure phase, lasting 10 to 17 years. Exposure to the noninvolved (surface) worker population would occur during the 6-year period while this group was working on surface facility closure. Exposure would continue to members of the public and a smaller number of workers throughout the period for subsurface facility closure.

Table 4-7 lists estimated annual doses and total doses from radon-222 during the closure phase to maximally exposed individuals and potentially affected populations from radionuclide releases from subsurface facilities. Section 4.1.7 discusses potential radiological impacts from these doses. The total dose to the offsite maximally exposed individual would be 3 to 9.4 millirem for the closure phase. The maximum annual dose to the offsite maximally exposed individual would be about 0.4 to 0.87 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 3 to 6 percent of this standard. The population dose would be 57 to 180 person-rem for the closure phase. The dose to the maximally exposed noninvolved (surface) worker at the South Portal would be 0.014 to 0.07 millirem for the entire closure phase. The dose to the noninvolved repository (surface) worker population would range from 0.004 to 0.015 person-rem. Highest doses for this phase—both total and annual—would be under conditions of largest waste package spacing, which would require the largest repository and the longest time (17 years) to close the repository.

Table 4-7. Radiation doses to maximally exposed individuals and populations from radon-222 releases from the subsurface during closure phase.[a,b]

	Operating mode			
	Higher-temperature		Lower-temperature	
Impact	Total	Maximum annual[c]	Total	Maximum annual[c]
Dose to public				
MEI[c] (millirem)	3	0.4	4.3 - 9.4	0.57 - 0.87
80-kilometer population[d] (person-rem)	57	7.4	83 - 180	10 - 16
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[e] (millirem)	0.014	0.0018	0.024 - 0.07	0.003 - 0.0063
Yucca Mountain noninvolved worker population (person-rem)	0.004	0.00052	0.007 - 0.015	0.00088 - 0.0014
Nevada Test Site noninvolved worker population[f] (person-rem)	0.0031	0.00041	0.0046 - 0.0099	0.00058 - 0.00089

a. Numbers are rounded to two significant figures.
b. The closure phase would begin after the 76 to 300 years of monitoring and last 10 to 17 years.
c. MEI = maximally exposed individual located at the southern boundary of the land withdrawal area.
d. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).
e. Maximally exposed noninvolved worker location would be at the South Portal Development Area.
f. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.2.5 Total Impacts to Air Quality from All Phases

The nonradiological air quality analysis examined concentrations of criteria pollutants in comparison to National Ambient Air Quality Standards. These standards are for periods ranging from 1 hour up to an annual average concentration of pollutant, so a “total” project impact is presented as no more than the highest single year. The highest concentrations of all criteria pollutants except PM_{10} would be less than 1 percent of applicable standards in all cases. PM_{10} would also be less than 1 percent of the applicable limits except: it would be less than 2 percent of the annual limit and 6 percent of the 24-hour limit during the construction phase; less than 2 percent of the 24-hour limit during the operation and monitoring phase; and less than 4 percent of the 24-hour limit during the closure phase.

The radiological impacts to air quality for the entire project are quantified by evaluating the doses to the populations of potentially exposed workers and members of the public. Results are not presented for impacts to individuals because the project duration (from 115 to 341 years) would be longer than the 70-year lifetime used for analysis purposes. Individual impacts for the various project activity periods (as long as 50 years for workers and 70 years for the public for the longer monitoring period) are discussed in the previous sections.

Table 4-8 lists total radiological air quality impacts for the entire Yucca Mountain Repository project. This table includes impacts for the higher-temperature repository operating mode and the range of impacts for the lower-temperature operating mode. The higher-temperature operating mode would have lower radiological air quality impacts, because it would have the shortest project duration (115 years), smallest excavated repository volume and therefore lowest releases of naturally occurring radon-222 and decay products, the primary dose contributor.

Table 4-8. Total radiation doses to exposed individuals and populations for all phases.[a,b,c]

Release	Operating mode			
	Higher-temperature		Lower-temperature[d]	
	Entire project	Annual	Entire project	Annual
Dose to public				
MEI[e] (millirem)	31	0.73	44 - 62	1 - 1.3
80-kilometer population[f] (person-rem)	930	14	1,900 - 3,900	20 - 26
Dose to noninvolved workers (person-rem)				
Maximally exposed noninvolved worker[e] (millirem)	30	2	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker[g] population	1.7	0.1	1.7 - 2.4	0.12 - 0.13
Nevada Test Site noninvolved worker population[h]	0.048	0.00063	0.1 - 0.21	0.0009 - 0.0012

a. Numbers are rounded to two significant figures.
b. The duration of all project phases (construction, operation and monitoring, and closure) would range from 115 to 341 years.
c. Section 4.1.7.5.3 describes radiological health impacts.
d. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
e. MEI = maximally exposed individual. The public MEI would be exposed 70 years and the noninvolved worker MEI exposed 50 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. For air quality impacts, noninvolved workers include those at the repository surface who could be exposed to releases of radon-222 and its decay products from the exhaust shafts.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

4.1.3 IMPACTS TO HYDROLOGY

The following sections describe environmental impacts to the hydrology of the Yucca Mountain region, first from performance confirmation activities (Section 4.1.3.1), then from construction, operation and monitoring, and closure actions. The latter actions are presented in terms of surface water (Section 4.1.3.2) and groundwater (Section 4.1.3.3). Chapter 5 discusses long-term postclosure impacts resulting from repository performance.

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction and operation activities that would be susceptible to erosion, areas affected by permanent changes in flow, and downstream areas that would be affected by eroded soil or potential spills of contaminants. The analysis of surface-water impacts considered known perennial and intermittent lakes, surface streams, and washes.

The analysis assessed groundwater impacts to determine the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability of groundwater for use during construction and operations, and the potential that such use would affect other users. The region of influence for this analysis included aquifers under the areas of construction and operations that DOE could use to obtain water and downstream aquifers that repository use or long-term releases from the repository could affect. The evaluation of groundwater impacts considered perennial yields of groundwater resources in comparison to known uses and requirements.

4.1.3.1 Impacts to Hydrology from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be unlikely to cause large impacts to the surface hydrology at the Yucca Mountain site, where there are no perennial streams or other permanent surface-water bodies. As during site characterization, DOE would design roads or other surface disturbances to minimize alterations to natural flowpaths and nearby washes (such as Drill Hole Wash). (See Section 4.1.4.2 and Chapter 11 for discussions of protection of waters of the United States.)

The preconstruction testing and performance confirmation studies would not adversely affect groundwater quality because DOE would use only limited quantities and types of hazardous materials, and activities involving such materials would be in strict accordance with applicable regulations and DOE Orders. State and Federal environmental, health, and safety regulations, as well as its own internal rules would require DOE to manage hazardous materials carefully and to clean up and report any measurable spills or releases promptly. Thus, the control of hazardous materials would be such that the potential for groundwater contamination would be very low.

DOE would use existing groundwater wells to support performance confirmation activities (for example, wells J-12 and J-13). In addition, it could use the existing C-well complex for aquifer testing and for a backup water supply. The Department expects water use from wells J-12 and J-13 to be similar to or less than that experienced during site characterization, which averaged about 0.093 million cubic meters (75 acre-feet) a year from 1993 through 1997 (not including test pumping at the C-well complex) (see Table 3-16). This would equal approximately 2 to 9 percent of the estimated perennial yield of the hydrographic basin (Jackass Flats) of 1.1 million to 4.9 million cubic meters (880 to 4,000 acre-feet) a year (see Table 3-11). Therefore, adverse effects on the quantity of groundwater resources would be unlikely. DOE could conduct pump tests of the aquifer at the C-well complex during performance confirmation activities. Under such tests, the amount pumped probably would be similar to that pumped during site characterization [about 0.23 million cubic meters (190 acre-feet) per year]. Even with this additional quantity, water demand would still be well below the lowest estimates of the basin's perennial yield, and DOE would manage water withdrawn from the C-well complex as part of aquifer testing in the same manner it has used for site characterization activities (that is, discharged to a spreading basin with State of Nevada concurrence and credit for groundwater recharge).

4.1.3.2 Impacts to Surface Water from Construction, Operation and Monitoring, and Closure

There are no perennial streams or other permanent surface-water bodies in the Yucca Mountain vicinity. The occurrence of natural surface water is limited to short periods when precipitation lasts long enough or is of high enough intensity to generate runoff to the natural drainage channels. In rare instances, runoff from the area of the proposed repository and support facilities could reach such channels as Drill Hole Wash, then flow to Fortymile Wash, and eventually reach the Amargosa River. Under most precipitation events, however, water simply soaks into the ground and is usually lost to evapotranspiration or, if there is enough to accumulate in drainage channels, soaks into the dry washes before traveling far, becoming potential recharge in these localized areas. Other potential sources of surface water associated with the

Proposed Action, such as the water used for dust suppression, would be a result of pumping groundwater to the surface.

The surface-water impacts of primary concern are related to the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage
- Impacts to floodplains

Discharges of Water to the Surface

During the 5-year initial construction phase, and during the operations period that would follow (lasting 24 years or 50 years if surface aging was used), sources of surface water other than precipitation would be limited primarily to the water DOE would use for dust suppression on the surface and below ground (with accumulations pumped back to the surface). Sanitary sewage, which would be piped to septic tank and drainage field systems, would not produce surface water. In addition, DOE would pump fresh water (groundwater) at the site and store it in tanks.

DOE has evaluated dust suppression actions during characterization efforts at the Yucca Mountain site for their potential to cause deep infiltration of water (DIRS 102547-CRWMS M&O 1997, pp. 51 to 53 and 73). The evaluation concluded that the amount of water actually used for dust suppression activities during site characterization has not caused water to penetrate the underlying rock. Studies at the site on infiltration capacities of natural soils (DIRS 100147-Flint, Hevesi, and Flint 1996, pp. 57 to 59) show that runoff or deep infiltration would not occur as a result of water applications for dust suppression. DOE would establish controls as necessary to ensure that water application for subsurface and surface dust control did not affect repository performance or result in large impacts.

Water would be pumped from the surface facilities to the subsurface during the construction phase and operations period while subsurface development continued. DOE would collect excess water from dust suppression applications and water percolating into the repository drifts, if any, and pump it to the surface, generating another source of surface water. Water pumped from the subsurface would go to an evaporation pond at the South Portal Development Area. The pond would be lined with heavy plastic to prevent infiltration or water loss. Table 4-9 lists discharge estimates to the South Portal evaporation pond for the higher- and lower-temperature operating modes. During the operations period, the quantity of water discharged would vary in proportion to the amount of subsurface excavation. Annual discharges under the lower-temperature operating mode would increase in comparison to those from the higher-temperature operating mode because of increased waste package spacing and the associated increase in drift excavation. DOE would investigate the feasibility of recycling all, or a portion, of this water.

The operation of heating and air conditioning systems at the North Portal Operations Area would result in the generation of wastewater (primarily from cooling tower blowdown and water softener regeneration) that DOE would discharge to the North Portal evaporation pond, which would be lined with heavy plastic. In addition, water collected from the emplacement side of the subsurface area, if any, would be pumped to this pond after verification that it was not contaminated. Table 4-10 lists the estimated discharges to the North Portal evaporation pond for the operating modes during the operations period. The estimates of annual discharge would change under the lower-temperature operating mode depending on the specific operating parameters used. These changes would be due primarily to a small change in the estimated size (total floor space) of the facilities.

The South Portal evaporation pond would be double-lined with polyvinyl chloride and would have a leak detection system (DIRS 102303-CRWMS M&O 1998, p. 16). The North Portal evaporation pond, which would be primarily for cooling and heating process water, would, at a minimum, have a polyvinyl

Table 4-9. Annual water discharges to South Portal evaporation pond.[a,b]

Phase	Operating mode	
	Higher-temperature[a,b]	Lower-temperature[a,c]
Construction		
Discharge (cubic meters)[d]	6,800	8,500 - 9,000
Duration (years)	5	5
Operations period		
Discharge (cubic meters)	3,500	4,400 - 7,500
Duration (years)	22[e]	22[e]

a. Estimated at 13 percent of the process water pumped to the subsurface based on Exploratory Studies Facility construction experience.
b. Source: DIRS 150941-CRWMS M&O (2000, pp. 6-7 and 6-12).
c. Source: DIRS 155515-Williams (2001, pp. 13 and 17; Parts 1 and 2, pp. 5 and 9).
d. To convert cubic meters to gallons, multiply by 264.18.
e. Discharge to this pond is during subsurface development activities only.

chloride liner (DIRS 102303-CRWMS M&O 1998, pp. 16 and 28). With proper maintenance, both ponds should remain intact and would have no effect on the site. DOE would build a third, much smaller evaporation pond, as appropriate, at the concrete batch plant to facilitate collection and management of equipment rinse water. Chapter 9 discusses mitigation measures associated with the Proposed Action.

Table 4-10. Annual water discharges to North Portal evaporation pond during operations period.

Factor	Operating mode	
	Higher-temperature[a]	Lower-temperature[a,b]
Discharge (cubic meters)[c]	34,000	31,000 - 36,000
Duration (years)	24	24

a. Source: DIRS 152010-CRWMS M&O (2000, p. 52).
b. Source: DIRS 155516-Williams (2001, p. 4)
c. To convert cubic meters to gallons, multiply by 264.18.

Other uses of water during the operations period would occur in the repository facilities and would have little, if any, potential to generate surface water. These sources include the washdown stations and the pools in the Waste Handling Building. Water from either of these sources would be managed as liquid low-level radioactive waste and treated in the Waste Treatment Building. Water from the treatment process would be recycled to the extent practicable, and residues and solids would be prepared for offsite shipment and disposal.

The quantity of water discharges to the surface during the monitoring period and from closure would be similar to or less than those discussed for the initial construction phase and operations period. The evaporation ponds would no longer be in use but other manmade sources of surface water should be very similar; water storage tanks would still be in use, there would be sanitary sewage, and dust suppression activities would occur.

Potential for Contaminant Spread to Surface Water

The potential for contaminants to reach surface water would generally be limited to the occurrence of a spill or leak followed by a rare precipitation or snow melt event large enough to generate runoff. DOE would design each facility that would contain radioactive material at the repository site such that flooding would not threaten material in the facility. Consistent with DOE Order 6430.1A, *General Design Criteria*, Nuclear Regulatory Commission licensing requirements, and national standards such as those of the American National Standards Institute, facilities in the Radiologically Controlled Area (for the management of radioactive materials) would be built to withstand the probable maximum flood. For example, if the footprint of a facility in the Radiologically Controlled Area was within the predicted natural inundation level of the probable maximum flood, one way to protect the facility would be to build up its foundation so it would be above the flood level and associated debris flows (DIRS 102303-CRWMS M&O 1998, pp. 32 to 37). Other facilities would be designed and built to withstand a 100-year flood, consistent with common industrial practice. Inundation levels expected from a 100-year, 500-year, regional maximum, or even probable maximum flood would represent no hazard to the proposed repository subsurface facilities, the portals of which would be at higher elevations than the flood-prone areas (DIRS 151945-CRWMS M&O 2000, p. 7.3-4 and Figure 7.3-3).

DOE would minimize the potential for a contaminant spread by managing spills and leaks in the proper and required manner. Activities at the site would adhere to a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to comply with environmental regulations and to ensure best management practices. The plan would describe the actions DOE would take to prevent, control, and remediate spills. It would also describe the reporting requirements that would accompany the identification of a spill. As an additional measure to reduce the potential for contaminant release to surface water, DOE would build two stormwater retention basins near the North Portal Operations Area, one for the Radiologically Controlled Area and one for the balance-of-plant facilities. The basin for the Radiologically Controlled Area would contain the runoff from a storm consistent with the probable maximum flood. The basin for the balance-of-plant area would contain the runoff from a storm consistent with a 100-year flood.

The primary sources of potential surface-water contaminants during both the construction and the operation and monitoring phases would be the fuels (diesel and gasoline) and lubricants (oils and greases) needed for equipment. Fuel oil storage tanks would be in place relatively early in the construction phase. Each would be constructed with an appropriate containment structure (consistent with 40 CFR Part 112). Other organic materials such as paints, solvents, strippers, and concrete additives would be present during the construction phase but in smaller quantities and much smaller containers.

The operation and monitoring phase would involve the use of other chemicals, particularly in the Waste Treatment Building, where the liquid low-level radioactive waste treatment process, for example, would include the use of liquid sodium hydroxide and sulfuric acid. In addition, this phase would require relatively small quantities of cleaning solvents [up to about 1,300 liters (330 gallons) per year] (DIRS 152010-CRWMS M&O 2000, p. 51). Because these materials would be used and stored inside buildings and managed in accordance with applicable environmental, health, and safety standards and best management practices, there would be little potential for contamination to spread through contact with surface water.

In addition, liquid low-level radioactive waste present in the Radiologically Controlled Area would be treated in the Waste Treatment Building to stabilize such material with cement or grout before it left the facility. Similarly, hazardous waste and mixed waste would be maintained and moved in closed containers. These conditions would minimize the potential for spills and leaks that could lead to contaminant spread.

Radioactive materials present during the operation and monitoring phase would be managed in the Radiologically Controlled Area of the North Portal Operations Area. This would include the Carrier Parking Area and Carrier Preparation Building across Midway Valley Wash to the northeast, and the aging pads if used for the lower-temperature operating mode. The radiological materials would always be in containers or casks except when they were in the Waste Handling and Waste Treatment Buildings. In those buildings, facility system and component design would prevent inadvertent releases to the environment; drainlines would lead to internal tanks or catchments, air emissions would be filtered, fuel pools would have secondary containment and leak detection, and other features would have similar safety or control components. If a lower-temperature operating mode with surface aging was implemented, the fuel blending pools (total capacity of 5,000 MTHM) would be eliminated from the design. A fuel transfer pool associated with the assembly transfer system would still be present, but would represent a much smaller volume of water. Elimination of the blending pools would eliminate a source of potential water releases, but in all cases the probability of leakage from any of these pools would be very low, given current design engineering, and construction standards and the importance of leak prevention.

During the operation and monitoring phase a surface environmental monitoring system would monitor the surface areas and groundwater for radioactive and hazardous substance release (DIRS 101779-DOE 1998, Volume 2, p. 4-37). It would also monitor facility effluents and testing wells for the presence of radiological or other hazardous constituents that could indicate a release from an operation activity. The combination of minor sources of surface water and the prevention and control of contaminant releases would limit the potential for contaminant spread by surface water.

Monitoring and maintenance activities after the completion of emplacement would involve a decrease in general activities at the site and, accordingly, less potential for spills or releases to occur. Decontamination actions that would follow emplacement could present other risks, due to the possible presence of decontamination chemicals and the start of new work activities. DOE would continue to use controls, monitoring, response plans and procedures, and regulatory requirements to limit the potential for spills or releases to occur from these activities.

The potential for contaminant spread would be limited during the closure phase and would be reduced further during postclosure care of the site. As in the other phases, engineering controls, monitoring, and release response requirements would limit the potential for contaminants to reach surface water.

Potential for Changes to Surface Water Runoff or Infiltration Rates

Construction activities that disturbed the land surface would alter the rate at which water could infiltrate the disturbed areas. A maximum of about 2.8 square kilometers (690 acres) of land would be disturbed during the construction and operation and monitoring phases of the higher-temperature operating mode. Including land already disturbed during the characterization activities, the total would be about 4.3 square kilometers (1,060 acres). The amount of newly disturbed land would be about 4.0 to 4.5 square kilometers (990 to 1,100 acres) under the lower-temperature operating mode. Depending on the type of disturbance, the infiltration rate could increase (for example, in areas with loosened soil) or decrease (for example, in areas where construction activities had compacted the soil or involved the installation of relatively impermeable surfaces like asphalt pads, concrete surfaces, or buildings). Most of the land disturbance during construction would result in surfaces with lower infiltration rates; that is, the surfaces would be less permeable than natural soil conditions and would cause an increase in runoff. However, DOE expects the change in the amount of runoff actually reaching the drainage channels to be relatively minor, because repository construction would affect a relatively small amount of the natural drainage area. For example, almost all of the area that would be disturbed at the proposed repository site is drained by Drill Hole Wash, which includes Midway Valley Wash as a major tributary. The maximum new disturbance of 4.5 square kilometers (1,100 acres) would be small (less than 12 percent) in comparison to the approximate 40 square kilometers (9,900 acres) that comprise the drainage area of Drill Hole Wash by the time it reaches Fortymile Wash (DIRS 102783-Squires and Young 1984, p. 2).

Monitoring and maintenance activities would not disturb additional land and, therefore, would have no notable impacts to runoff rates in the area. Reclamation of previously disturbed land would restore preconstruction runoff rates.

DOE anticipates that closure activities would disturb only land that had been previously disturbed during earlier phases. The removal of structures and impermeable surfaces would decrease runoff from these areas and should put them in a condition closer to that of the surrounding natural surfaces. Reclamation efforts such as topsoil replacement and revegetation should help restore the disturbed areas to nearly natural conditions in relation to infiltration and runoff rates. The construction of monuments as long-lasting markers of the site use would be likely to make their locations impervious to infiltration but, as described above, change in runoff from the relatively small impervious areas would be small in comparison to the total drainage area.

Potential for Altering Natural Surface-Water Drainage

Construction activities can alter natural drainage systems if they (1) increase the erosion and sedimentation process (material eroded from one location in the drainage system is subsequently deposited in another location), or (2) place a structure, facility, or roadway in a drainage channel or flood zone. Section 4.1.4.4 discusses erosion issues. The focus of this section is the planned construction of structures, facilities, or roadways over natural drainage channels.

Pursuant to Executive Order 11988, *Floodplain Management*, each Federal agency is required, when conducting activities in a floodplain, to take action to reduce the risk of flood damage; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values served by floodplains. DOE regulations implementing this Executive Order are at 10 CFR Part 1022.

Repository-related structures could affect small drainage channels or washes. DOE expects to control surface-water drainage in these washes with minor diversion channels, culverts, or similar drainage control measures. Some transportation-related construction, operation, and maintenance actions would occur in the floodplains of as many as four washes in the Yucca Mountain vicinity. Construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. Appendix L contains a floodplain/wetlands assessment that describes in detail the actions that DOE could take. The analysis indicated that consequences of the actions DOE could take in or near the floodplains of these four washes would be minor and unlikely to increase the impacts of floods on human health and safety or harm the natural and beneficial values of the affected floodplains. It also indicated that there are no delineated wetlands at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on the route DOE selected.

Closure of the repository should involve no actions that would alter natural drainage beyond those from the other phases. Areas where facilities were removed would be graded to match the natural topography to the extent practicable. Monuments would not be constructed in locations where they would alter important drainage channels or patterns and, in the process, back up or divert any meaningful volume of runoff.

4.1.3.3 Impacts to Groundwater from Construction, Operation and Monitoring, and Closure

This section identifies potential impacts to groundwater. Section 3.1.4 describes existing groundwater characteristics and uses in the Yucca Mountain vicinity. The potential impacts discussed in this section would be associated with the repository project, which would include construction, operation and monitoring, and closure. Chapter 5 describes potential impacts as a result of the repository's long-term performance after closure. The following impacts would be of primary concern while the repository was open:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

This section discusses these potential impacts in general terms, primarily in relation to changes from existing conditions.

Infiltration Rate Changes

As discussed in Section 4.1.3.2, surface-disturbing construction activities would alter infiltration rates in the repository area. In the Yucca Mountain environment, water rarely travels long distances on the surface before infiltrating into the ground or evaporating. If construction activities resulted in disturbed land that was loose or broken up, local infiltration would increase and the amount of runoff reaching nearby drainage channels would decrease accordingly. Conversely, completed construction that involved either compacted soil or facility surfaces (concrete pads, asphalt surfaces, etc.) would result in less local infiltration and more water available to reach the drainage channels and then infiltrate into the ground. However, the location where infiltration takes place can have an effect on what happens to the water. That is, in some locations the water would be more likely to contribute to deep infiltration and possibly even to recharge to the aquifer.

In the semiarid environment in the Yucca Mountain vicinity, surface areas where meaningful recharge to the aquifer can occur are generally places such as Fortymile Wash (Section 3.1.4.2.2), which collects runoff from a large drainage area. Enough water can accumulate there to cause deep infiltration and occasional recharge. There is not enough precipitation or runoff in most other areas to generate infiltration deep enough to prevent its loss to evapotranspiration between precipitation events. In general, this will be the case even when land disturbance causes an increase in local infiltration. The most likely way that recharge could be affected would be for land disturbance to cause additional runoff (as from constructed facilities) that could accumulate in areas such as Fortymile Wash, and the effect would be a potential for increased recharge. However, given the dry climate and relatively small amount of potentially disturbed area in relation to the surrounding unchanged areas, the net change in infiltration would be small.

Surface disturbances could change infiltration rates in areas where the layer of unconsolidated material is thin and the disturbance resulted in the exposure of fractured bedrock. Cracks and crevices in the bedrock could provide relatively fast pathways for the movement of water to deep parts of the unsaturated zone (DIRS 151945-CRWMS M&O 2000, p. 8.9-8), where the water would be less susceptible to evapotranspiration. These effects would be applicable to the Emplacement and Development Shaft Operations Areas, which would be on steeper terrain, uphill from the South Portal Development Area and North Portal Operations Area, where the depth of unconsolidated material is likely to be thin. However, the amount of disturbed land would be small in comparison to the surrounding undisturbed area, and any net change in infiltration would be small.

Subsurface activities would have the potential to affect the amount of water in the unsaturated zone that could infiltrate more deeply, possibly even as recharge to the aquifer. These activities would include measures to minimize the quantities of standing or infiltrating water in the repository by pumping it to the surface for evaporation. Potential sources of this water could include water percolating in from the unsaturated zone and water pumped from the surface for underground dust control measures. The latter should involve the largest volume by far, much of which would be brought to the surface with the excavated rock generated by tunnel boring machines. Excess water in the subsurface would evaporate (the underground areas would be ventilated), be collected and pumped to the surface, or be lost as infiltration to cracks and crevices in the rock. During excavation of the Exploratory Studies Facility, DOE tracked water use and used water tracers to help track its movement. The purpose of these actions was to minimize loss of this water to the subsurface environment and to ensure that subsurface water use did not adversely affect either future repository performance or ongoing site investigations (DIRS 102197-CRWMS 1997, all). This careful use of water in the subsurface would continue during additional repository excavation. Given the mechanisms to remove the water (excavated rock removal, ventilation, and pumping) and the careful use of water in the subsurface, along with the relatively minor importance of Yucca Mountain recharge to the local and regional groundwater system, DOE expects perturbations in recharge through Yucca Mountain to be of small impact to the local and regional groundwater system.

No additional land disturbance would occur from monitoring and maintenance activities and, therefore, there would be no notable impacts to infiltration rates in the area. There would be no additional land disturbance during closure. The implementation of soil reclamation and revegetation would accelerate a return to more natural infiltration conditions. If DOE built a monument (or monuments) to provide a long-lasting marker for the site, its location could be impermeable and thus could generate minor amounts of additional runoff to drainage channels.

Potential for Contaminant Migration to Groundwater

Section 4.1.3.2 discusses the types of potential contaminants that could be present at the repository surface facilities during the various phases of its active life. It also discusses the possibility of spills or releases of these materials to the environment.

To pose a threat to groundwater, a contaminant would have to be spilled or released and then carried down either by its own volume or with infiltrating water. The depth to groundwater, the thickness of alluvium in the area, and the arid environment would combine to reduce the potential for a large contaminant migration, as would adherence to regulatory requirements and plans such as a Spill Prevention Control and Countermeasure Plan (see Section 4.1.3.2). Section 4.1.8 further discusses the potential for onsite accidents that could involve a release of contaminants. Chapter 5 discusses the long-term postclosure release of contaminants from the waste packages emplaced in the repository.

Groundwater Resources

The quantity of water necessary to support the Proposed Action would be greatest during the initial construction phase and the operation and monitoring phase. Peak demand would occur while DOE was emplacing nuclear material in completed drifts (tunnels) at the same time it was developing other drifts. Table 4-11 summarizes the estimated water demands during these two phases and during closure. Water demand during construction would depend on the operating mode employed. The lower-temperature operating mode would involve emplacement of less spent fuel per unit of repository footprint area, which correlates with increased excavation and increased water to support that excavation.

Table 4-11. Annual water demand for construction, operation and monitoring, and closure.[a]

Phase	Duration (years)	Water demand (acre-feet per year)[a]	
		Higher-temperature	Lower-temperature
Construction	5	160	190 - 210
Operation and monitoring			
Operations period[b]			
Emplacement and development	22	230	250 - 290
Subsequent emplacement only	2 or 28	180	90 - 190
Monitoring period			
Initial decontamination	3	220	200 - 230
Subsequent monitoring and caretaking	73 - 300	6	3 - 6
Closure	10 - 17	81	70 - 84

a. To convert acre-feet to cubic meters, multiply by 1,233.49. Acre-feet are presented because of common public knowledge of this area.

b. Development of the subsurface area would last 22 years for the Proposed Action and emplacement would continue another 2 years without aging. If aging was included, emplacement would not be completed until 28 years beyond the completion of development.

As listed in Table 4-11, water demand during the initial construction phase would range from about 200,000 to 260,000 cubic meters (160 to 210 acre-feet) per year under the range of operating modes. Water demand during the operations period would also vary by operating mode and could range from about 280,000 to 360,000 cubic meters (230 to 290 acre-feet) per year. Once subsurface development was complete and only emplacement was occurring, the estimated annual water demand would range from 110,000 to 230,000 cubic meters (90 to 190 acre-feet). The low end of this range would occur only if the aging facility was included, but it would last for about 26 years while the spent nuclear fuel on the surface pad completed its 30-year cooldown period and DOE gradually moved it to the subsurface. The first 3 years of the monitoring period would include facility decontamination efforts and would require water at a rate varying from 250,000 to 280,000 cubic meters (200 to 230 acre-feet) per year. After the first 3 years, water demand would drop substantially to estimated levels of only 3,700 to 7,400 cubic meters (3 to 6 acre-feet) for the duration of the monitoring period. The closure phase would require about 86,000 to 100,000 cubic meters (70 to 84 acre-feet) per year.

The water demand would be met by pumping from wells in the Jackass Flats hydrographic area, using existing wells J-12, J-13, and the C-well complex. Nevada Test Site activities in this same area also withdraw water from this hydrographic area. This ongoing demand from Nevada Test Site activities has an effect on the affected environment and would continue to represent part of the demand from the Jackass Flats hydrographic area. Consequently, this additional water demand is discussed here and as part of the cumulative impacts in Chapter 8.

DOE evaluated potential impacts of the water demands on area groundwater resources by three methods:

- Consideration of impacts observed or measured during past water withdrawals
- Comparison of the proposed demand to the perennial yield of the aquifer supplying the water
- Groundwater modeling efforts to assess any changes the proposed demand would have on groundwater elevations and flow patterns

Groundwater Demand During Construction

During the initial construction phase, the estimated water demand from the Jackass Flats hydrographic area would be about 540,000 to about 600,000 cubic meters (440 to 490 acre-feet) a year, including the ongoing demand from Nevada Test Site activities [projected to be 340,000 cubic meters (280 acre-feet) a year (DIRS 103226-DOE 1998, Table 11-2, p. 11-6)]. This quantity is very similar to the roughly 490,000 cubic meters (400 acre-feet) withdrawn from the Jackass Flats area in 1996 (see Chapter 3, Table 3-16). The level of water demand during the construction phase probably would result in declines in water levels in the production wells and nearby. DOE expects the amount of decline to be similar to the groundwater level fluctuations discussed in Chapter 3, Section 3.1.4.2.2 (see Table 3-17), during which elevation decreases as large as 6 to 12 centimeters (2.4 to 4.7 inches) occurred in the production wells over a 6-year period. However, this decline would diminish to undetectable levels as the distance from the repository increased and would result in very small effects to the overall groundwater system.

Effect of Operations on Groundwater Perennial Yield

As the Proposed Action would move from construction into the operation and monitoring phase, groundwater withdrawal rates would increase. The following discussion of impacts centers on comparisons to the perennial yield of the groundwater basin supplying the water.

Perennial yield is the estimated quantity of groundwater that can be withdrawn annually from a basin without depleting the reservoir. As discussed in Chapter 3, Section 3.1.4.2, the estimated perennial yield of the aquifer in the Jackass Flats hydrographic area is between 1.1 million and 4.9 million cubic meters (880 and 4,000 acre-feet) (DIRS 104954-Thiel 1997, p. 8). However, as indicated in footnote f to Table 3-11 in Chapter 3, the low estimate of perennial yield for Jackass Flats is accompanied by the qualification that 370,000 cubic meters (300 acre-feet) is attributed to the eastern one-third of the area, and 720,000 cubic meters (580 acre-feet) is attributed to the western two-thirds where wells J-12 and J-13 are located. This distinction was made to be consistent with the belief of some investigators that the two portions of Jackass Flats have different general flow characteristics. Assuming this is correct, the most conservatively low estimate of perennial yield applicable to the location of wells J-12 and J-13 would be 720,000 cubic meters (580 acre-feet). The highest estimated water demand during the operation and monitoring phase would not exceed this lowest estimate of perennial yield, and it would represent only about 7 percent of the higher estimate of perennial yield.

A past DOE application for a water appropriation from Jackass Flats resulted in a State Engineer's ruling (DIRS 105034-Turnipseed 1992, pp. 9 to 11) that described the perennial yield of Jackass Flats (Hydrographic Area 227A) as 4.9 million cubic meters (4,000 acre-feet). The same ruling identified the estimated annual recharge for the western two-thirds of this hydrographic area as 720,000 cubic meters (580 acre-feet). Based on this information, the estimates of perennial yield for this hydrographic area range from consideration of only the amount of recharge that occurs in the area to inclusion of underflow that enters the area from upgradient groundwater basins. If the groundwater is basically in equilibrium under current conditions (which should be a reasonable assumption based on the stability of the water table elevation), then withdrawing more than 720,000 cubic meters probably would result in additional underflow entering the immediate area to maintain the equilibrium level. Under this scenario, pumping more than 720,000 cubic meters from the western portion of Jackass Flats would be unlikely to cause a depletion of the reservoir, and instead could result in shifting of the general groundwater flow patterns. Because the amount pumped would be much less than the upper estimates of perennial yield (that is, the total amount of available water moving through the area, not just the recharge from precipitation), changes in general flow patterns probably would be small.

With the addition of repository water usage to the baseline demands from Nevada Test Site activities, the highest estimated demand from the Jackass Flats area during the initial construction phase would be about 600,000 cubic meters (490 acre-feet) per year. This demand would be below the lowest estimate of the area's perennial yield [720,000 cubic meters (580 acre-feet) for the western two-thirds of Jackass Flats]. Maximum repository water demands would occur during the operations period (Table 4-11), which when combined with the baseline demands from Nevada Test Site activities would approach but still be below the lowest perennial yield estimate. None of the water demand estimates would approach the high estimates of perennial yield [4.9 million cubic meters (4,000 acre-feet)].

On a regional basis in the Alkali Flat-Furnace Creek groundwater basin, the heaviest water demand is in the Amargosa Desert. Over the period of the repository project's need for water, additional water consumption in upgradient hydrographic areas would to some extent decrease the availability of water in the valley (DIRS 103099-Buqo 1999, pp. 37, 38, and 52). That is, consumption would not necessarily exceed the perennial yield of the Jackass Flats hydrographic area, but it could reduce the long-term amount of underflow that would reach the Amargosa Desert, effectively decreasing the perennial yield of that hydrographic area. However, the maximum projected demands for the repository and the Nevada Test Site during the construction phase [about 600,000 cubic meters (490 acre-feet) a year] and the operation and monitoring phase [about 700,000 cubic meters (570 acre-feet)] would be small in comparison to the 17 million cubic meters (14,000 acre-feet) pumped in the Amargosa Desert annually from 1995 through 1997 (see Table 3-11). The demand of the repository and the Nevada Test Site would be even a smaller fraction of the perennial yield of 30 million to 40 million cubic meters (24,000 to 32,000 acre-feet) in the Amargosa Desert.

Potential Changes to Groundwater Elevation

Two separate modeling efforts have assessed potential changes to groundwater elevations and flow patterns as a result of water demands from the proposed repository action. One study (DIRS 145966-

CRWMS M&O 2000, all) was performed by Thiel Engineering Consultants for DOE; the other study (DIRS 145962-Tucci and Faunt 1999, all) was performed by the U.S. Geological Survey. Both efforts included the modeling of baseline conditions that included historical water withdrawals from the Jackass Flats area followed by modeling of future water withdrawals that include the baseline and an additional annual water demand of 530,000 cubic meters (430 acre-feet) for the proposed repository. The studies focused on the predicted differences between the baseline and future simulations in the groundwater flow regime of Jackass Flats and surrounding hydrographic areas, particularly the Amargosa Desert (see Figure 3-17). The Thiel Engineering Consultants study included the use of transient models (DIRS 145966-CRWMS M&O 2000, p. 2) to project changes in groundwater levels and flow patterns. It utilized several different assumed groundwater withdrawal scenarios over this area, with and without the water demand for the repository project, and simulated the withdrawal scenarios for 100 years. The U.S. Geological Survey effort compared the results of two steady-state simulations (baseline and predictive future) of the regional groundwater flow system. Results of the simulations indicated that there would be groundwater elevation differences (between conditions with and without the Proposed Action) as described in the following summary statements:

- The Thiel Engineering Consultants study predicted a water elevation decrease of up to 3 meters (10 feet) within about 1 kilometer (0.6 mile) of the Yucca Mountain production wells as a result of the Proposed Action's water demand (DIRS 145966-CRWMS M&O 2000, p. 86). The U.S. Geological Survey model resulted in similar projections, predicting a water level decrease of less than 2 meters (6.6 feet) at distances of a few kilometers from the production wells (DIRS 145962-Tucci and Faunt 1999, p. 13).

- The models predicted water elevation decreases at the town of Amargosa Valley ranging from less than 0.4 meter (1.2 feet) (DIRS 145966-CRWMS M&O 2000, all) to 1.1 meters (3.6 feet) (DIRS 145962-Tucci and Faunt 1999, p. 13).

- Both models generated predictions of the reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area that would result from the Proposed Action. The Thiel Engineering Consultants (DIRS 145966-CRWMS M&O 2000, p. 89) study estimates a flow reduction of about 160,000 cubic meters (130 acre-feet) per year after 100 years of pumping. The U.S. Geological Survey (DIRS 145962-Tucci and Faunt 1999, p. 13) effort estimates 180,000 cubic meters (150 acre-feet) per year at steady-state conditions.

The Thiel Engineering Consultants modeling effort looked at numerous locations and pumping scenarios throughout the groundwater region. The results indicated that in all areas of the Amargosa Desert, the decreases in groundwater elevation attributed to the Proposed Action would be minor in comparison to those simulated for the areas without the Proposed Action (DIRS 145966-CRWMS M&O 2000, pp. 173 to 184). Both models evaluated a hypothetical Yucca Mountain Project water demand of 530,000 cubic meters (430 acre-feet) per year, which is the quantity planned for the site's application for a water appropriation. As listed in Table 4-11, the highest estimate of the Proposed Action's annual water demand is only about 67 percent of this quantity. Had this smaller number been used in the models, a corresponding decrease in the predicted effects would have resulted. The Proposed Action's higher periods of water demand [that is, periods with annual water demand near or above 250,000 cubic meters (200 acre-feet)] would total only about 30 years compared to the 100 years of demand at the higher rate used in the Thiel Engineering Consultants study.

Monitoring Period

Water demand for monitoring and maintenance activities would be much less than that for emplacement and development activities, particularly after the completion of decontamination activities, which would take place during the first 3 years of the monitoring period. Routine monitoring and maintenance activities would involve minimal water needs.

Closure Phase

The annual demand during closure would vary by a small amount based on the operating mode used, but would be less than 30 percent of the maximum demand during the operation and monitoring phase and, similarly, would have minor impacts on groundwater resources.

Summary of Impacts to Hydrology

The conclusions of the evaluations discussed in this section are as follows:

- Repository operation would result in minor changes to runoff and infiltration rates.
- The potential for flooding at the repository site is extremely small.
- Water demand under highest consumption conditions would be below the Nevada State Engineer's ruling of perennial yield (the amount that can be withdrawn annually without depleting reserves) for the Jackass Flats groundwater basin. The highest demand conditions in combination with ongoing Nevada Test Site demand from the same basin would also be below the lowest estimates of perennial yield.
- The combined water demand of the repository and the Nevada Test Site would, at most, have minor impacts on the availability of groundwater in the Amargosa Valley in comparison to the quantities of water already being withdrawn there.

DOE filed an application for permanent water rights with the State of Nevada for the projected water needs to meet DOE's responsibilities under the NWPA. Uses for the water would include, but not be limited to, road construction, facility construction, drilling, dust suppression, drift and pad construction, testing, culinary, domestic, and other related site uses. On February 2, 2000, the Nevada State Engineer denied the application on the basis that the proposed use threatens to prove detrimental to the public interest because the proposed use (that is, supporting the repository action) is prohibited by existing State law. On March 2, 2000, DOE filed an appeal of the State Engineer's decision (DIRS 151945-CRWMS M&O 2000, pp. 9.5-5 and 9.5-6). On October 15, 2001, the U.S. Court of Appeals (9th Circuit) remanded the case back to the Nevada District Court for a hearing on the merits. At the time this EIS was prepared, the appeal was still in process and a final outcome for the water appropriation application had not been determined.

4.1.4 IMPACTS TO BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for affecting sensitive species (plants and animals) and their habitats, including areas of critical environmental concern; sensitive, threatened, or endangered species, including their habitats; jurisdictional waters of the United States, including wetlands; and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of game animals. DOE expects the overall impacts to biological resources to be very small. Biological resources in the Yucca Mountain region include species typical of the Mojave and Great Basin Deserts and generally are common throughout those areas. Neither the removal of vegetation from the small area required for the repository nor the very small impacts to some species would affect regional biodiversity and ecosystem function.

Section 4.1.4.1 describes potential impacts to biological resources and soils from preconstruction testing and performance confirmation activities. Section 4.1.4.2 describes potential impacts to biological resources from construction, operation and monitoring, and closure. Section 4.1.4.3 describes the evaluation of the severity of potential impacts to biological resources. Section 4.1.4.4 describes potential impacts to soils from construction, operation and monitoring, and closure.

4.1.4.1 Impacts to Biological Resources and Soils from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities could require additional land disturbance, and current vehicle traffic at the site of the proposed repository would continue. Impacts to biological resources from additional land disturbance could consist of the loss of a small amount of available habitat for terrestrial plant and animal species, including desert tortoises, in widely distributed land cover types and the deaths of a small number of individuals of some terrestrial species. The actual amount of additional land disturbance, if any, is uncertain. DOE expects it to be much less than the quantity of disturbance during site characterization.

The limited habitat loss from additional land disturbance would have little impact on plant and animal populations because habitats similar to those at Yucca Mountain are widespread locally and regionally. Similarly, the deaths of small numbers of individuals of some species, primarily burrowing species of small mammals and reptiles, would have little impact on the regional populations of those species. The animal species at the Yucca Mountain site are generally widespread throughout the Mojave or Great Basin Deserts.

Impacts to desert tortoises from preconstruction testing and performance confirmation would be less than impacts that occurred during site characterization, during which five tortoises have been killed on roads at Yucca Mountain (DIRS 104593-CRWMS M&O 1999, p. 3-12). Habitat loss during the peak of site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). Because the desert tortoise is a *threatened species*, it would continue to receive special consideration during land-disturbing activities. DOE would continue to work with the U.S. Fish and Wildlife Service and would implement the terms and conditions required by the Service to minimize impacts to desert tortoises at the site (see Appendix O). Thus, preconstruction testing and performance confirmation would have very little or no impact on the desert tortoise population at Yucca Mountain or along roads traveled to the site.

The potential for soil impacts such as erosion would increase slightly, but erosion control measures, such as dust suppression, would ensure that impacts were very small.

4.1.4.2 Impacts to Biological Resources from Construction, Operation and Monitoring, and Closure

This section describes potential short-term impacts to biological resources at the Yucca Mountain site from construction, operation and monitoring, and closure activities. The primary sources of such impacts would be related to habitat loss or modification during facility construction and operations and to human activities, such as increased traffic, associated with the repository. In addition, this section identifies and evaluates potential impacts to vegetation; wildlife; special status species; and jurisdictional waters of the United States, including wetlands, over the projected life of the project and during each phase of the project.

Routine releases of radioactive materials from the repository would consist mainly of naturally occurring radon-222 and its decay products (see Section 4.1.2 and Appendix G, Section G.2). These releases would result in very small doses to plants and animals around the repository. Estimated doses to humans working and living near the site would be very small (as described in Section 4.1.7). The International

Atomic Energy Agency has concluded that chronic dose rates less than 100 *millirad* per day to plants and animals are unlikely to cause measurable detrimental effects in populations of even the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53). Expected dose rates to plants and animals would be much less than 100 millirad per day. Therefore, no detectable impacts to biological resources would occur as a result of normal releases of radioactive materials from the repository, and the following sections do not consider these releases.

Impacts to Vegetation

The construction of surface facilities and the disposition of rock excavated during subsurface construction would remove or alter vegetation. Much of the construction would occur in areas in which site characterization activities had already disturbed the vegetation; however, construction would also occur in undisturbed areas near the previously disturbed areas. Subsurface construction would continue after emplacement operations began, and the disposal of excavated rock would eliminate vegetation in the area covered by the excavated rock pile. The total amount of land cleared of vegetation would vary among the repository operating modes (Table 4-12).

Table 4-12. Land cover types in the land withdrawal area and the amount of each that repository construction and disposal of excavated rock would disturb (square kilometers).[a,b]

			Area that would be disturbed	
Land cover type[c]	Area in Nevada	Land withdrawal area	Higher-temperature	Lower- temperature
Blackbrush	9,900	140	0.0	0.0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	2.2	2.4 - 3.6
Sagebrush	67,000	16	0.0	0.0
Salt desert scrub	58,000	20	0.0	0.0
Previously disturbed	NA[d]	4	1.5	1.5
Totals[e]	***NA***	***600***	***4.3***	***4.5 - 6.0***

a. Source: Derived from facility diagrams from DIRS 104523-CRWMS M&O (1999, all) and land cover types maps and vegetation associations (DIRS 102303-CRWMS M&O 1998, all) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. A small area (0.016 square kilometer) of the piñon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
d. NA = not applicable.
e. Totals might differ from sums due to rounding.

Five of the 65 different land cover types (defined primarily by dominant vegetation) identified in the State of Nevada occur in the approximately 600-square-kilometer (230-square-mile) analyzed land withdrawal area around the repository site (Table 4-12). Surface disturbances resulting from repository activities would occur in three of these land cover types and in previously disturbed areas (Table 4-12). Repository construction would disturb less than 1 percent of the withdrawal area, which would be an extremely small percentage of the undisturbed vegetation available in the withdrawal area.

Repository construction, including the disposal of material in the excavated rock pile after the start of emplacement, would occur primarily in previously disturbed areas or areas dominated by creosote-bursage and Mojave mixed scrub.

Repository construction activities in undisturbed vegetation could result in additional areas where colonization by exotic plant species could occur. Exotic species that are currently present on the site (see Section 3.1.5.1.1) would be the most likely *invasive species*. *Native species* could be suppressed in areas colonized by exotic species and there could be an increase in fire fuel load associated with dried annual plant species. Because the undisturbed vegetated area that would be disturbed by construction is small compared to the total undisturbed vegetated area, impacts to native species and the threat of increased fires would also be small.

Studies from 1989 to 1997 indicated that site characterization activities had very small effects on vegetation adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-2 through 2-4). Therefore, impacts to vegetation from repository construction probably would occur only as a result of direct disturbance, such as during site clearing. Little or no disturbance of additional vegetation would occur as a result of monitoring and maintenance activities before closure. DOE would reclaim lands no longer needed for repository operation.

Activities associated with the closure of the repository could involve the removal of structures and reclamation of areas cleared of vegetation for the construction of surface facilities. Closure would involve minimal, if any, new disturbance of vegetation. Reclamation activities would enhance the recovery of native vegetation in disturbed areas and reduce colonization by exotic species.

Impacts to Wildlife

The construction of surface facilities and excavated rock disposal would lead to habitat losses for some terrestrial species (Chapter 3, Section 3.1.5); however, habitats similar to those at Yucca Mountain (identified by land cover type) are widespread locally and regionally. In addition to habitat loss, the conversion of undisturbed land to industrial uses associated with the repository would result in the localized deaths of individuals of some species, particularly burrowing species of small mammals and reptiles. Birds, carnivores, and ungulates (mule deer or burros) at the repository site would be less likely to be killed during construction because they would be able to move away from areas of human activity.

The construction of new roads, surface facilities, and other infrastructure would lead to fragmentation of previously undisturbed habitat. Nevertheless, DOE anticipates impacts to wildlife populations to be very small because large areas of undisturbed and unfragmented habitat would be available away from disturbed areas.

Animal species present at the repository location are generally widespread throughout the Mojave or Great Basin Deserts and the deaths of some individuals due to repository construction and habitat loss would have little impact on the regional populations of those species. Site characterization activities had no detectable effect on populations of small mammals, side-blotched lizards, and desert tortoises in areas adjacent to the activities (DIRS 104593-CRWMS M&O 1999, pp. 2-4, 2-5, 2-7, and 3-10 to 3-12).

In addition to direct losses due to the construction of surface facilities and excavated rock disposal, individuals of some species would be killed by vehicles traveling to and from the Yucca Mountain site during the construction, operation and monitoring, and closure phases (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). These losses would have a very small effect on populations because species at the site are widespread. No species would be threatened with extinction, either locally or globally.

Noise and ground vibrations generated during repository construction and operations could disturb wildlife and cause some animals to move away from or avoid the source of the noise. Impacts to wildlife from noise and vibration, if any, would decline as the distance from the source of the noise (the repository) increased. Noise levels would drop below the limit of human hearing at a distance of about 6 kilometers (3.7 miles) from the repository (see Section 4.1.9) and no noise-related impacts to wildlife would be likely at that distance. Animals may acclimate to the noise, limiting the area affected by repository-related noise to the immediate vicinity of the source of the noise (heavy equipment, diesel generators, ventilation fans, etc.).

Several animals classified as game species by the State of Nevada (Gambel's quail, chukar, mourning doves, and mule deer) are present in low numbers in the analyzed Yucca Mountain land withdrawal area.

Adverse impacts to these species would be unlikely, and offsite hunting opportunities probably would not decline.

DOE would dispose of industrial wastewater in lined evaporation ponds in the North Portal Operations Area and South Portal Development Area. Wildlife would be attracted to the water in these ponds to take advantage of this otherwise scarce resource. Individuals of some species could benefit from the water, but some animals could become trapped in the ponds, depending on the depth and the slope of the sides. Monitoring at similar lined evaporation ponds on the Nevada Test Site has shown that a wide variety of animal species use the ponds and that DOE could avoid losses of animals by reducing the slopes of the ponds or by providing an earthen ramp at one corner of the lined pond (DIRS 103075-Bechtel 1997, p. 31). Appropriate engineering would minimize potential losses to wildlife.

DOE does not anticipate adverse effects on wildlife that used the nonhazardous, nontoxic wastewater discharged to the evaporation ponds. Industrial wastewater routed to the evaporation pond at the North Portal would be nonhazardous. DOE anticipates that the primary chemical constituents in the water would be sodium and calcium carbonates, with smaller amounts of chlorides, sulfates, and fluorides. Metal constituents could include potassium, zinc, iron, magnesium, and manganese. Wastewater discharged to the South Portal evaporation pond would be nontoxic wastewater derived from dust suppression activities; it would contain small particles of mined rock along with Portland Cement and fine aggregate particles from concrete mix plants. DOE would maintain the pH of the water within a defined range through the addition of acceptable additives. Water quality would be monitored and appropriate measures to protect wildlife would be implemented.

DOE would construct a landfill for construction debris and sanitary solid waste. The landfill could attract scavengers such as coyotes and ravens. Frequent covering of the sanitary waste disposed of in the landfill could minimize use by scavenger species.

After the completion of emplacement, human activities and vehicle traffic would decline, as would impacts of those actions on wildlife, with further declines in activities and impacts after repository closure. Animal species would reoccupy the areas reclaimed during closure activities.

Impacts to Special Status Species

The desert tortoise is the only resident animal species in the analyzed land withdrawal area listed as threatened under the Endangered Species Act of 1973 (16 U.S.C. 1531, *et seq.*). There are no endangered or candidate animal species and no species that are proposed for listing (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). Repository construction would result in the loss of a very small portion of the total amount of desert tortoise habitat at the northern edge of the range of this species in an area where the abundance of desert tortoises is low (DIRS 102869-CRWMS M&O 1997, pp. 6 to 12; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12).

Based on past experience, DOE anticipates that human activities at the site could directly affect individual desert tortoises. During site characterization activities, 28 tortoises and two tortoise nests were relocated because of threats from construction activities (DIRS 103194-CRWMS M&O 1998, pp. 3 to 17; DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). All but one of the 28 individual relocations and both nest relocations were successful. Five tortoises (including the one unsuccessful relocation) have been killed as a result of site characterization activities; all were killed by vehicles on roads (DIRS 104593-CRWMS M&O 1999, pp. 3-11 and 3-12). DOE would conduct surveys and would move tortoises that it found; however, based on experience from site characterization, DOE anticipates the deaths of small numbers of individual tortoises from vehicle traffic and construction activities during the repository construction, operation and monitoring, and closure phases.

Although these losses would cause a small decrease in the abundance of desert tortoises in the immediate vicinity of the repository site, they would not affect the long-term survival of the local or regional population of this species. Yucca Mountain is surrounded to the east, south, and west by large tracts of undisturbed tortoise habitat on government property, and desert tortoises are widespread at low densities throughout this region. Habitat loss caused by transportation and other activities during site characterization did not have a detectable effect on the survival, reproduction, behavior, or disease status of desert tortoises living adjacent to construction activities at Yucca Mountain (DIRS 104294-CRWMS M&O 1999, all). In addition, the abundance of ravens at Yucca Mountain did not increase as a result of site characterization activities (DIRS 102236-CRWMS M&O 1998, pp. 9 through 12), and ravens were not an important cause of mortality of small tortoises during that period (DIRS 103195-CRWMS M&O 1998, p. 8).

The U.S. Fish and Wildlife Service has concluded that tortoise populations are depleted for more than a kilometer on either side of heavily used roads (DIRS 102475-Brussard et al. 1994, p. D12). The increase in traffic to Yucca Mountain (see Appendix J, Section J.3.6) would contribute to the continued depression of populations immediately adjacent to U.S. Highway 95, but would not increase the threat to the long-term survival of desert tortoise populations in southern Nevada.

As required by Section 7 of the Endangered Species Act, DOE has completed consultations with the Fish and Wildlife Service concerning the effects of repository construction, operation and monitoring, and closure on the desert tortoise. The U.S. Fish and Wildlife Service has issued a Biological Opinion establishing reasonable and prudent measures and terms and conditions to ensure that implementation of the Proposed Action would not jeopardize the desert tortoise (see Appendix O). The Biological Opinion also contains an incidental take permit. DOE would implement all the measures and terms and conditions of the Biological Opinion to protect the desert tortoise around Yucca Mountain.

The bald eagle and peregrine falcon have been observed once each on the Nevada Test Site and might migrate through the Yucca Mountain region. If present at all, these species would be transient and would not be affected. Bald eagles are classified as threatened under the Endangered Species Act. The State of Nevada classifies the bald eagle and the peregrine falcon as endangered.

Several animal species considered sensitive by the Bureau of Land Management [two bats—the long-legged myotis and fringed myotis—and the western chuckwalla, burrowing owl, and Giuliani’s dune scarab beetle; (see Chapter 3, Section 3.1.5)] occur in the analyzed land withdrawal area. Impacts to the bat species would be very small because of their low abundance on the site and broad distribution. Impacts to the Western chuckwalla and burrowing owl would be very small because they are widespread regionally and are not abundant in the land withdrawal area. Giuliani’s dune scarab beetle has been reported only in the southern portion of the land withdrawal area, away from any proposed disturbances.

Monitoring and closure activities at the repository would have little impact on desert tortoises, or Bureau of Land Management sensitive species. Over time, vegetation would recover on disturbed sites and indigenous species would return. As the habitat recovered over the long term, desert tortoises and other special status species at the repository site would recolonize areas abandoned by humans.

Impacts to Wetlands

There are no known naturally occurring jurisdictional wetlands (that is, wetlands subject to permitting requirements under Section 404 of the Clean Water Act) on the repository site, so no impacts to such wetlands would occur as a result of repository construction, operation and monitoring, or closure. In addition, repository construction, operation and monitoring, and closure would not affect the four manmade well ponds in the Yucca Mountain region. Repository-related structures could affect as much as 2.8 kilometers (1.7 miles) of ephemeral washes, depending on the size and location of such facilities as the excavated rock storage area. Although no formal delineation has been undertaken, some of these washes might be waters of the United States. After selecting the location of facilities, DOE would conduct a formal delineation, as appropriate, to confirm there are no wetlands at Yucca Mountain; formally delineate waters of the United States near the surface facilities; and, if necessary, develop a plan to avoid when possible, and otherwise minimize, impacts to those waters. If repository activities would affect waters of the United States, DOE would consult with the U.S. Army Corps of Engineers and obtain permit coverage for those impacts. If the activities were not covered under a nationwide permit, DOE would apply to the Corps of Engineers for a regional or individual permit. By implementing the mitigation plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be minimized.

4.1.4.3 Evaluation of Severity of Impacts to Biological Resources

DOE evaluated the magnitude of impacts to biological resources and classified the severity of potential impacts as none, very low, or low, as listed and described in Table 4-13.

Table 4-13. Impacts to biological resources.

Phase or period	Flora	Fauna	Special status species	Wetlands	Overall
Initial construction	Very low/low; removal of vegetation from as much as 4.5 square kilometers[a] in widespread communities	Very low; loss of small amount of habitat and some individuals of some species	Low; loss of small amount of desert tortoise habitat and small number of individual tortoises	None	Very low/low; loss of small amount of widespread but undisturbed habitat and small number of individuals
Construction, operation, and monitoring					
Emplacement and development	Very low/low; disturbance of vegetation in areas adjacent to disturbed areas	Very low; deaths of small number of individuals due to vehicle traffic and human activities	Low; potential deaths of very few individuals due to vehicle traffic	None	Very low new impacts to biological resources
Monitoring and maintenance	Very low; no new disturbance of natural vegetation	Very low; same as for operation, but smaller due to smaller workforce	Very low; same as for operation, but smaller due to smaller workforce	None	Very low; small numbers of individuals of some species killed by vehicles
Closure	Very low; decline in impacts due to reduction in human activity	Very low; decline in number of individuals killed by traffic annually	Very low; decline in number of individuals killed by traffic annually	None	Very low; decline in impacts due to reduction of human activity
Overall rating of impacts	Very low/low	Very low	Very low/low	None	Very low

a. 4.5 square kilometers = 1,100 acres (6.0 square kilometers total area, including areas previously disturbed by site characterization).

4.1.4.4 Impacts to Soils from Construction, Operation and Monitoring, and Closure

This section identifies potential consequences to soils as a result of the Proposed Action. Soil-related issues associated with the Proposed Action include the following:

- Potential consequences of soil loss in disturbed areas, either from erosion or displacement
- *Soil recovery* from disturbances
- Potential for spreading contamination by relocating contaminated soils (if present)

Overall, impacts to soils would be minimal. DOE would use erosion control techniques to minimize erosion. Because soil in disturbed areas would be slow to recover, during the closure phase DOE would revegetate the area that it had not reclaimed after the temporary disturbances following construction.

Soil Loss

Land disturbed at the repository site could, at least for a short period, experience increased erosion. Erosion is a two-step process of (1) breaking away soil particles or small aggregates and (2) transporting those particles or aggregates. Land disturbance that removed vegetation or otherwise broke up the natural surface would expose more small materials to the erosion process, making the soil more susceptible to wind and water erosion. Activities during the construction and operation and monitoring phases would disturb varying amounts of land depending on the operating mode used for the repository. Most of the variation would be due to the emplaced waste being spaced further apart under the lower-temperature operating mode, resulting in more excavated rock being stored on the surface and more ventilation shafts extending from the repository to the surface. A decision to incorporate an aging facility would increase the amount of land disturbed. The highest estimate of newly disturbed land as a result of the Proposed Action is about 4.5 square kilometers (1,100 acres).

Site characterization activities at Yucca Mountain included a reclamation program with a goal to return the disturbed land to a condition similar to its predisturbance state (DIRS 154386-YMP 2001, p. 1). One of the benefits of achieving such a goal would be the minimization of soil erosion. The program included the implementation and evaluation of topsoil stockpiling and stabilization efforts that would enable the use of topsoil removed during excavation in future reclamation activities. The results were encouraging enough to recommend that these practices continue. This action would reduce the construction loss of the most critical type of soil. Fugitive dust control measures including water spraying and chemical treatment would be used as appropriate to minimize wind erosion of the stockpiled topsoil and excavated rock. Based on site characterization experience and the continued topsoil protection and erosion control programs, DOE does not anticipate much soil erosion during any phase of the project.

If the Proposed Action was implemented, program planning developed for site characterization (DIRS 104837-DOE 1989, pp. 2 and 20) specifies that reclamation would occur in all areas disturbed during characterization activities that are not needed for the operation of the repository. As a result, prior land disturbances should represent minimal soil erosion concern during the Proposed Action.

Recovery

Studies performed during the Yucca Mountain site characterization effort (DIRS 104837-DOE 1989, all; DIRS 102188-YMP 1995, all) looked at the ability of the soil ecology to recover after disturbances. These studies and experience at the Nevada Test Site indicate that natural succession on disturbed arid lands would be a very slow process (DIRS 104837-DOE 1989, p. 17; DIRS 102188-YMP 1995, p. 1-5). Left alone, and depending on the type or degree of disturbance and the site-specific environmental conditions, the recovery of

> **SOIL RECOVERY**
>
> The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

predisturbance conditions in this area could take decades or even centuries. With this in mind, soil recovery would be unlikely without reclamation. In general, soil disturbances would remain as areas without vegetation and, with the exception of built-up areas, would have an increased potential for soil erosion throughout the construction and operation and monitoring phases.

Contamination

Based on preconstruction testing and characterization activities that took place in the past (Chapter 3, Section 3.1.5.2), radiological and nonradiological characteristics of the site soils are consistent with the area background. Therefore, there would be no need for restrictions or concerns about contamination migration during construction or as a result of soil erosion. There would be a potential for spills or releases of contaminants to occur under the Proposed Action (as discussed in Section 4.1.3), but DOE would continue to implement a Spill Prevention, Control, and Countermeasures Plan [DIRS 104903-K/PB (1997, all) is an example] to prevent, control, and remediate soil contamination.

4.1.5 IMPACTS TO CULTURAL RESOURCES

This section describes impacts to cultural resources from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The evaluation of such impacts considered the potential for disrupting or modifying the character of archaeological or historic sites and other cultural resources. The evaluation placed particular emphasis on identifying the potential for impacts to historic sites and other cultural resources important to sustaining and preserving Native American cultures. The region of influence for the analysis included land areas that repository activities would disturb and areas in the analyzed land withdrawal area where impacts could occur.

DOE assessed potential impacts to cultural resources from these activities by (1) identifying project activities that could directly or indirectly affect archaeological, historic, and traditional Native American resources possibly eligible for listing on the *National Register of Historic Places*; (2) identifying the known or likely eligible resources in areas of potential impact; and (3) determining if a project activity would have no effect, no adverse effect, or an adverse effect on potentially eligible resources (36 CFR 800.9). Direct impacts would be those from ground disturbances or activities that would destroy or modify the integrity of a given resource considered eligible for listing on the National Register. Indirect impacts would result from activities that could increase the potential for adverse impacts, either intentional or unintentional (for example, increased human activity near potentially eligible resources could result in illicit collection or inadvertent destruction).

4.1.5.1 Impacts to Cultural Resources from Preconstruction Testing and Performance Confirmation

Land disturbances associated with preconstruction testing and performance confirmation activities could have direct impacts to cultural resources in the Yucca Mountain region of influence (see Chapter 3, Table 3-1). Before activities began, therefore, DOE would identify and evaluate archaeological or cultural resources sites in affected areas for their importance and eligibility for inclusion in the *National Register of Historic Places*. DOE would avoid such sites if practical or, if it was not practical, would conduct a data recovery program of the sites in accordance with applicable regulatory requirements and input from the official tribal contact representatives and document the findings. The artifacts from and knowledge about the site would be preserved. Improved access to the area could lead to indirect impacts, which could include unauthorized excavation or collection of artifacts. Workers would have required training on the protection of these resources from excavation or collection.

fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of repository components. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the Nuclear Waste Policy Act requires DOE to maintain the ability to retrieve emplaced waste for an appropriate period after the start of emplacement. Nuclear Regulatory Commission regulations at 10 CFR 63.111(e) specify a retrieval period of at least 50 years. Because of this requirement, the EIS analyzed the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 324 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. Some of the impacts that could occur during retrieval have been addressed in the Proposed Action under the lower-temperature operating mode with surface aging. This operating mode would include surface aging of up to two-thirds of the commercial spent nuclear fuel over a 50-year operations period (Chapter 2, Section 2.1.1.2.2). This aging facility could be used to store a portion of any spent nuclear fuel or high-level radioactive waste that would be retrieved.

This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

4.2.1.1 Retrieval Activities

If there was a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Chapter 2, Section 2.1.2.2).

On the surface, the retrieved waste packages would be loaded on a vehicle for transport to a Waste Retrieval and Storage Area in Midway Valley, about 3.7 kilometers (2.3 miles) from the North Portal Operations Area, to which DOE would build a rail line or roadway. Figure 4-5 shows the relationship between these areas. The Waste Retrieval and Storage Area would include a Waste Retrieval Transfer Building, support facilities, and a number of concrete storage pads. To retrieve and store 70,000 MTHM of spent nuclear fuel and high-level radioactive waste, these facilities would cover about 1.5 square kilometers (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2).

DOE based its selection of Midway Valley Wash as the site for retrieval activities on the following site selection criteria:

- Proximity to the repository North Portal Operations Area
- Retrieval of the waste in the shortest possible timeframe
- Adequate space for dry storage of 70,000 MTHM of waste
- No ground displacements due to earthquakes
- Siting outside the probable maximum flood zone
- Minimum costs for construction
- Minimum impacts to the environment

In the Waste Retrieval Transfer Building, the waste packages would be removed and placed in concrete storage modules (one container per module). The concrete module would protect the container and provide shielding. The module and container would then move to a concrete storage pad near the Waste Retrieval Transfer Building, where it would remain awaiting ultimate disposition. Figure 4-6 shows a concrete storage module design concept.

Studies of the strategies and options for retrieval (DIRS 100247-CRWMS M&O 1997, all) indicate that after a decision to retrieve the emplaced material, it would take about 10 years to plan the operation, procure the necessary equipment, and prepare the Waste Retrieval and Storage Area; subsequently, about 3 years would be needed for the initial construction of facilities and storage areas. After initial construction, the retrieval operations would require another 11 years, concurrent with an additional 7 years of storage area construction. DOE performed an impact analysis for the retrieval contingency only for the higher-temperature repository operating mode. Since 70,000 MTHM of spent nuclear fuel and high-level radioactive waste would be emplaced under the Proposed Action for all operating modes, the analysis of impacts for this operating mode is sufficient to describe the types and magnitudes of impacts that would occur if DOE implemented the retrieval contingency. Retrieval could be accomplished more quickly than the initial emplacement because limitations in material shipping and delivery as well as emplacement preparation (for example, waste package welding) would not be encountered.

4.2.1.2 Impacts of Retrieval

The following sections present the results of the environmental impact analysis for the retrieval contingency. They consider the construction of the Waste Retrieval and Storage Area, retrieval of the waste packages and their movement to the surface and to the Waste Retrieval and Storage Area, and the loading of the waste packages in concrete storage modules and their placement on concrete storage pads.

4.2.1.2.1 *Impacts to Land Use and Ownership from Retrieval*

Retrieval would cause no land use and ownership impacts during the construction of the Waste Retrieval and Storage area because the retrieval area would be on lands already withdrawn and under DOE control. DOE would develop the Waste Retrieval and Storage area on a 1.5-square-kilometer (380-acre) area approximately 3.7 kilometers (2.3 miles) north of the North Portal Operations Area in Midway Valley (see Figure 4-5). If DOE used surface aging under the lower-temperature repository operating mode, the

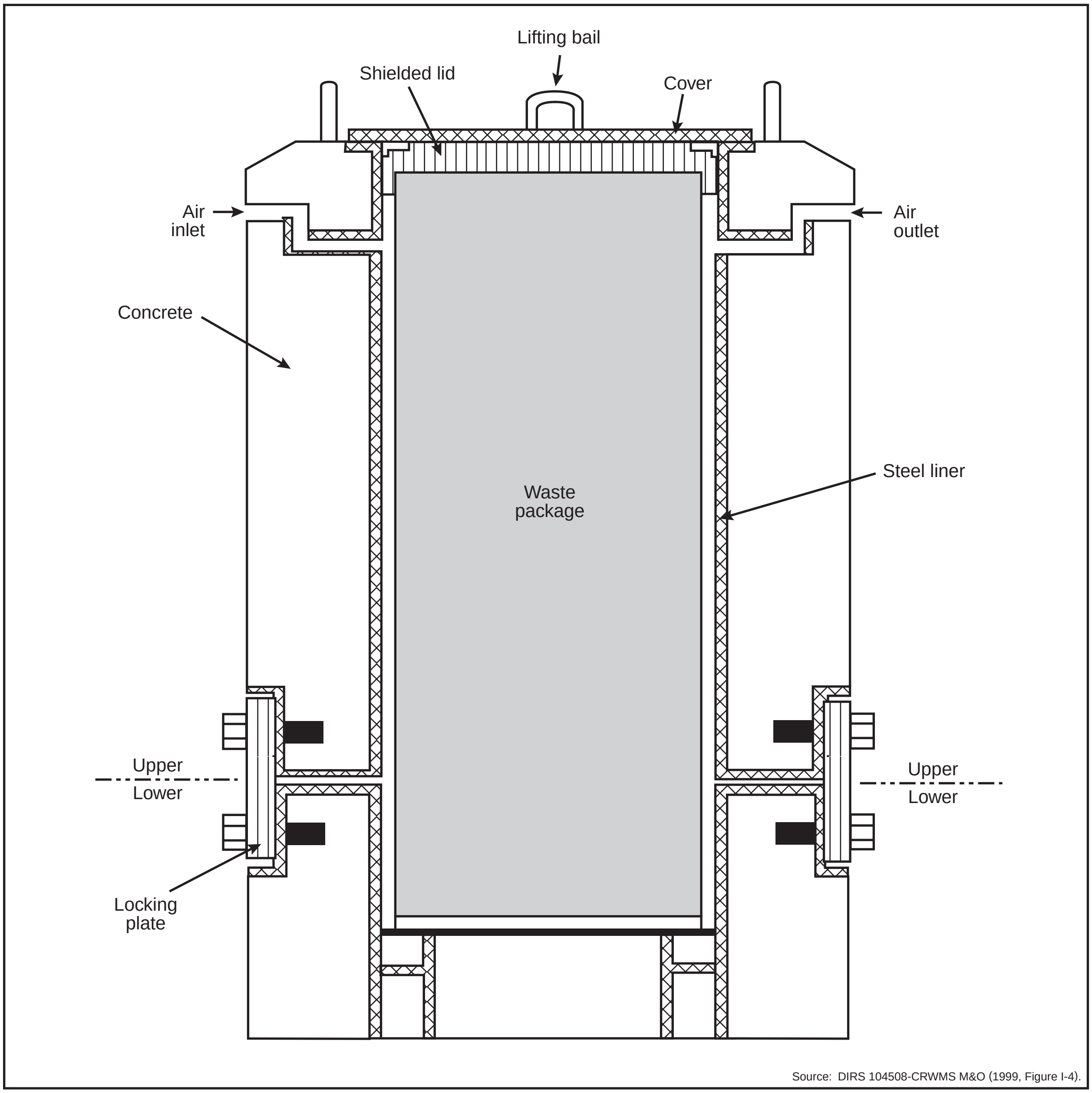


Figure 4-6. Typical concrete storage module design, vertical view.

aging pads could be available for use during retrieval operations, reducing the additional area disturbed for retrieval.

4.2.1.2.2 *Impacts to Air Quality from Retrieval*

The construction of the Waste Retrieval and Storage Area and the movement of the spent nuclear fuel and high-level radioactive waste to the surface would result in air quality impacts. The analysis considered both radiological and nonradiological impacts. No radiological air quality impacts would occur during the placement of the storage containers in concrete storage modules, assuming the containers remained intact and free from leaks during handling. However, radon-222 would be released from the active ventilation of the subsurface.

Nonradiological Air Quality Impacts. DOE evaluated nonradiological air quality impacts from the retrieval of materials from the repository for (1) the construction of a Waste Retrieval and Storage Area and (2) the retrieval process. Construction and retrieval activities would result in releases of nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10}. Retrieval activities would not involve subsurface excavation or result in disturbance of the excavated rock pile, so no releases of cristobalite would occur.

Construction equipment would release nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} from fuel consumption. Fugitive dust, assumed to be all PM_{10}, would also be released during construction from earthmoving activities and operation of a concrete batch plant in the North Portal Operations Area. The analysis did not take credit for the standard construction dust suppression measures that DOE would implement to lower the projected PM_{10} concentrations. Table 4-53 lists calculated concentrations for criteria pollutant impacts at the location of the public maximally exposed individual and compares these concentrations to regulatory limits. The nitrogen dioxide, sulfur dioxide, carbon monoxide, and PM_{10} concentrations at the location of the maximally exposed individual would be less than 2 percent of the applicable regulatory limits in all cases.

Table 4-53. Criteria pollutant impacts to public maximally exposed individual from retrieval (micro-grams per cubic meter).[a,b]

Pollutant	Averaging time	Regulatory limit[c]	Maximum concentration[d]	Percent of regulatory limit
Nitrogen dioxide	Annual	100	0.023	0.023
Sulfur dioxide	Annual	80	0.0022	0.0028
	24-hour	365	0.018	0.0049
	3-hour	1,300	0.14	0.011
Carbon monoxide	8-hour	10,000	0.20	0.0020
	1-hour	40,000	1.3	0.0033
Particulates (PM_{10}) ($PM_{2.5}$)	Annual	50 (15)	0.23	0.45
	24-hour	150 (65)	2.8	1.9

a. Appendix G, Section G.1, contains detailed information on the radiological air quality analysis.
b. All numbers except regulatory limits are rounded to two significant figures.
c. Regulatory limits from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
d. Sum of the highest concentrations at the accessible site boundary regardless of direction.

Radiological Air Quality Impacts. During retrieval activities subsurface ventilation would continue, resulting in releases of naturally occurring radon-222 and its decay products in the ventilation exhaust. Subsurface ventilation would continue for the duration of retrieval, lasting about 14 years with 3 years of initial construction (10 total years of construction), followed by 11 years of retrieval operations. Table 4-54 lists estimated annual and total doses from 14 years of retrieval activities to maximally exposed individuals and potentially affected populations from radon-222 released from subsurface facilities.

4.2.1.2.3 *Impacts to Hydrological Resources from Retrieval*

4.2.1.2.3.1 Surface Water. The retrieval activity that could have surface-water impacts would be the construction of the Waste Retrieval and Storage Area, which would disturb an area of 1.5 square kilometers (380 acres) (DIRS 152010-CRWMS M&O 2000, Table I-2).

Potential for Runoff Rate Changes. The total disturbed area would include areas cleared to support construction equipment and materials, facilities, and concrete storage pads. If DOE retrieved all the waste, the storage pad area would account for about 0.48 square kilometer (120 acres) of the disturbed land (DIRS 152010-CRWMS M&O 2000, Table I-1, p. I-12). Including the areas covered by facilities, roadways, and queuing areas, about half of the land disturbance would result in surface areas that would provide almost no infiltration, so precipitation would result in runoff from the Waste Retrieval and

Table 4-54. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during the retrieval period.[a,b]

Impact	Total	Annual
Dose to public		
Maximally exposed individual[c] (millirem)	2.7	0.19
80-kilometer[d] population[e] (person-rem)	50	3.6
Dose to noninvolved (surface) workers		
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.019	0.0040
Yucca Mountain noninvolved worker population (person-rem)	0.0045	0.00039
Nevada Test Site noninvolved worker population[g] (person-rem)	0.0031	0.00033

a. Appendix G, Section G.2, contains detailed information about the radiological air quality analysis.
b. Construction and retrieval activities would last 14 years.
c. At the southern boundary of the land withdrawal area.
d. 80 kilometers = 50 miles.
e. Approximately 76,000 individuals within 80 kilometers of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be at the South Portal Development Area.
g. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Storage Area. As described in Section 4.1.3.2, if precipitation did not generate runoff from surrounding areas, the runoff from the storage area could travel to otherwise empty drainage channels, but would not go far. If precipitation generated runoff everywhere, there would be little difference in the quantity produced in the storage area; it just would occur earlier in the storm. In addition, a comparison of the 1.5 square kilometers (380 acres) of disturbed land to the estimated 12 square kilometers (3,000 acres) that make up the Midway Valley Wash drainage area (DIRS 108883-Bullard 1992, Table 5) indicates that changes in runoff and infiltration rates should have little impact on how the entire drainage area responded to precipitation events.

Potential for Altering Natural Drainage. The proposed location for the Waste Retrieval and Storage Area does not cross or intercept well-defined drainage channels with the exception of the northwest corner, which could be close to, or possibly overlay, a short stretch of the upper Midway Valley Wash. Other portions of the facility would be in an area where simple overland flow probably would dominate runoff events. Design layouts of the proposed facility call for the construction of an interceptor trench along the upstream (north) side of the area, extending down either side; this would prevent runoff from entering the storage facility and could be an alteration to existing drainage. If flow in this short stretch of the upper Midway Valley Wash was intercepted, it would be diverted around the facility and then back to the existing course. Siting criteria for this proposed facility state that it will be located in a manner to minimize the engineering needed to protect it against the probable maximum flood zone (DIRS 152010-CRWMS M&O 2000, p. I-5). Therefore, a probable maximum flood in this small wash would not affect the retrieved material.

Potential for Flooding. The Waste Retrieval and Storage Area would be outside the probable maximum flood zone, although natural drainage might be altered to ensure this is the case. The interceptor trench on the north side of the facility would accommodate the highest quantities of runoff that could reasonably be present. Therefore, there would be no reasonable potential for flooding to affect the storage facility.

4.2.1.2.3.2 Groundwater. The retrieval activities that could have impacts on groundwater would be the construction of the Waste Retrieval and Storage Area and the retrieval of the emplaced material.

Potential for Infiltration Rate Changes. About half of the disturbed land would be covered by facilities, roadways, queuing areas, and storage pads. These facilities would be relatively impermeable to water, and would cause an additional amount of runoff to drainage channels in comparison to natural conditions. This additional runoff could cause a net increase in the amount of water to infiltrate these natural channels. The additional infiltration would move into the unsaturated zone and represent potential recharge to the aquifer, but it would be a minor amount in comparison to natural infiltration.

Impacts to Groundwater Resources. The estimated annual groundwater demand during retrieval would peak at about 170,000 cubic meters (140 acre-feet) a year (DIRS 152010-CRWMS M&O 2000, pp. I-18 and I-20; DIRS 150941-CRWMS M&O 2000, p. 6-20). No adverse impacts would be likely from this demand, which would be well within historic use rates.

4.2.1.2.4 *Impacts to Biological Resources and Soils*

The retrieval activity that could affect biological resources and soils would be the construction of the Waste Retrieval and Storage Area.

4.2.1.2.4.1 Impacts to Biological Resources from Retrieval. Impacts to biological resources would be similar to those described for construction and operations (see Section 4.1.4).

Impacts to Vegetation. The construction of retrieval facilities would disturb vegetation in an area that is presently undisturbed. The predominant land cover types in Midway Valley are blackbrush and Mojave mixed scrub, both of which are extensively distributed regionally and in the State of Nevada.

Impacts to Wildlife. Impacts to wildlife from the retrieval contingency would be similar to those described for the construction and operation of the repository. They would consist of limited habitat loss and the deaths of individuals of some species as a result of construction activities and vehicle traffic, and would be in addition to those associated with repository construction and operation.

Impacts to Special Status Species. Impacts to special status species from the retrieval contingency would be similar, and in addition to, those described for repository construction. They would consist of loss of a small portion of locally available habitat for the desert tortoise and the deaths of individual tortoises due to construction activities and vehicle traffic.

Impacts to Wetlands. No wetlands would be affected by activities associated with retrieval.

4.2.1.2.4.2 Impacts to Soils from Retrieval. Concrete pads, facilities, and roadways at the Waste Retrieval and Storage Area would eventually cover about half of the 1.5 square kilometers (380 acres) of disturbed land, but a sizable portion would remain as disturbed soil.

Soil Loss. Erosion concerns during the construction of the retrieval facilities would be the same as those described for the construction of the repository facilities (see Section 4.1.4.4). The types of soils encountered would be similar to, if not the same as, those encountered during the construction at the North Portal Operations Area and South Portal Development Area. As during other project activities, DOE would use dust suppression measures to reduce the disturbed land's erodibility.

After the construction of the retrieval facilities, much of the area would no longer be exposed to erosion forces because structures would cover the soil. However, the uncovered disturbed areas would be more susceptible to erosion than the surrounding natural areas. This would be the case until the disturbed land had time to reach equilibrium, including the reestablishment of vegetation. Erosion, if it occurred, probably would involve small amounts of soil from small areas. The amount of soil that could move downwind or downgradient should not present unusual concerns.

Recovery. DOE would reclaim disturbed lands when they were no longer needed for retrieval operations.

4.2.1.2.5 *Impacts to Cultural Resources from Retrieval*

The activity that could affect cultural resources would be the construction of the Waste Retrieval and Storage Area. The following sections discuss archaeological and historic resources and Native American interests in relation to retrieval.

Archaeological and Historic Resources. The results of earlier archaeological fieldwork indicate that there are no National Register-eligible archaeological resources on land recommended for the Waste Retrieval and Storage Area or near the proposed rail or road construction. Therefore, construction activities associated with retrieval probably would not result in direct impacts to National Register-eligible archaeological resources. As during repository construction and operation, increased activities and numbers of workers could increase the potential for indirect impacts to archaeological sites near the construction work.

Native American Interests. A Waste Retrieval and Storage Area in Midway Valley would be 500 meters (1,600 feet) west of the Yucca Wash local use area and Alice Hill. As described in DIRS 102043-AIWS (1998, all), these areas have cultural importance to Native Americans. There could be some direct or indirect impacts to these areas, depending on the specific locations of Native American significance boundaries.

4.2.1.2.6 *Impacts to Socioeconomics from Retrieval*

Waste retrieval activities would increase the repository workforce above that for ongoing monitoring and maintenance activities. A maximum annual employment of about 600 workers (DIRS 152010-CRWMS M&O 2000, pp. I-18 and I-20; DIRS 150941-CRWMS M&O 2000, p. 6-20) would be required during retrieval operations and concurrent storage pad construction. Retrieval would last about 14 years. Employment during retrieval would be less than during other project phases and would be unlikely to generate meaningful changes to the region of influence’s employment or economic measures. Regional impacts from retrieval would be small.

4.2.1.2.7 *Occupational and Public Health and Safety Impacts from Retrieval*

The analysis of health and safety impacts to workers considered industrial safety hazards and radiological impacts from construction and retrieval operations, as discussed earlier in this section. During construction activities DOE would build (1) the surface facilities necessary to handle retrieved waste packages and enclose them in concrete storage units in preparation for their placement on concrete storage pads, and (2) the concrete storage pads (see Section 4.2.1.1). No radioactive materials would be involved in the construction activities, so health and safety impacts would be limited to those associated with industrial hazards in the workplace. DOE expects initial construction to last about 3 years, with construction of the concrete storage pads continuing concurrently with retrieval operations for an additional 7 years.

During retrieval operations DOE would retrieve the waste packages and move them to the Waste Retrieval Transfer Building. Surface facility workers would unload the waste package from the transfer vehicle and place it on a concrete base. The waste package would be enclosed in a concrete storage unit that, with the waste package inside, would be placed on the concrete storage pad. Retrieval operations would last about 11 years. The analysis estimated the health and safety impacts from both industrial hazards and from radiological hazards from operations for both surface and subsurface workers.

Radiological impacts to the public could occur during all 14 years of the retrieval period when radon-222 and its decay products would be released to the environment in the exhaust stream from the subsurface ventilation system. There would be no other source of radiation exposure to the public, and no differentiation between the construction and operations activities.

The methods used to estimate health and safety impacts to workers and the public were the same as those used to estimate such impacts for the Proposed Action (see Appendix F, Section F.2.1). Additional information pertinent to health and safety impact analysis for retrieval is contained in Appendix F, Section F.4.

Industrial Health and Safety Impacts

Industrial health and safety impacts occur only to workers. As noted above, the only health and safety impacts during retrieval construction activities would be those from industrial hazards during normal workplace activities. These impacts are shown in Table 4-55. Projected fatality would be about 0.05 and projected lost workday cases would be about 46.

Table 4-55. Health and safety impacts from industrial hazards from retrieval construction, operations, and overall impacts.[a,b]

Worker group and impact category	Construction[c]	Retrieval operations[d]	Overall impact[e]
Involved workers			
Total recordable cases	80	35	120
Lost workday cases	38	15	53
Fatalities	0.04	0.03	0.07
Noninvolved workers			
Total recordable cases	16	35	51
Lost workday cases	8	17	25
Fatalities	0.01	0.04	0.04
All workers (totals)[e]			
Total recordable cases	96	70	170
Lost workday cases	46	32	78
Fatalities	0.05	0.07	0.12

a. Numbers rounded to two significant figures.
b. Sources: Calculated using impact rates from Appendix F, Table F-71 and full-time equivalent work years from Table F-70.
c. Source: Appendix F, Table F-73.
d. Source: Appendix F, Tables F-74 and F-75.
e. Totals might differ from sums of values due to rounding.

Industrial health and safety impacts from retrieval operations are also shown in Table 4-55, as are the overall impacts. Total impacts would be small, with an estimated total of 0.12 fatality and 78 lost workday cases.

Radiological Health Impacts

Radiological health impacts may occur to both workers and members of the public. Table 4-56 lists radiological health impacts for both surface and subsurface workers for the retrieval contingency as well as the total radiological impact to all workers. Most of the radiation dose would be to subsurface workers during retrieval operations, and Appendix F contains additional details on estimates of radiation dose to subsurface workers. Impacts would be small, with the latent cancer fatality likelihood for the maximally exposed individual being about 0.002. The calculated latent cancer fatality incidence to workers for retrieval would be 0.06.

The only source of radiation exposure to members of the public during construction and retrieval operations would be from releases of radon-222 and its decay products through the subsurface ventilation system exhaust. Table 4-54 presents the estimated radiation doses to members of the public from these releases.

Table 4-56. Radiological health impacts to workers from retrieval operations.[a,b,c]

Worker group and impact category	Surface facility workers	Subsurface facility workers	High/total[d]
Maximally Exposed Worker dose (rem)			*High*
Involved	0.28	5.9	5.9
Noninvolved	0	0.44	0.44
Probability of latent cancer fatality			
Involved	0.00011	0.002	0.002
Noninvolved	0	0.0002	0.0002
Worker population			*Total*
Collective dose (person-rem)			
Involved	8	120	130
Noninvolved	0	4	4
Total[e]	**8**	**130**	**140**
Number of latent cancer fatalities			
Involved	0.003	0.05	0.05
Noninvolved	0	0.002	0.002
Total[e]	**0.003**	**0.05**	**0.06**

a. Sources: Appendix F, Tables F-76 and F-77.
b. All impacts from operations. Radiological health impacts to workers during construction would be minimal.
c. Numbers are rounded to two significant figures.
d. Highest individual and population totals for the 11-year retrieval period.
e. Totals might differ from sums of values due to rounding.

Table 4-57 lists estimated radiological health impacts to the public for retrieval. The estimated radiological health impacts to members of the public from the retrieval contingency would be small. The likelihood of a latent cancer fatality for the maximally exposed individual would be about 0.0000013. The estimated latent cancer fatality incidence in the exposed population would be about 0.025.

Table 4-57. Radiological health impacts to the public for the retrieval period.

Worker group and impact category	Impact
Individual	
Maximally exposed individual dose (millirem)[a]	2.7
Latent cancer fatality probability	0.0000013
Population	
Collective dose (person-rem)[a]	50
Latent cancer fatality incidence	0.025

a. Source: Table 4-54.

4.2.1.2.8 *Impacts from Accidents During Retrieval*

During retrieval operations, activities at the repository would be essentially the reverse of waste package emplacement, except operations in the Waste Handling Building would not be necessary because the waste packages would not be opened. The handling accident scenario applicable for these operations would be bounded by the transporter runaway accident scenario evaluated in Section 4.1.8. The waste packages would be retrieved remotely from the emplacement drifts, transported to the surface, and transferred to a Waste Retrieval and Storage Area (DIRS 102702-CRWMS M&O 1997, all). This area would include a Waste Retrieval Transfer Building where the waste packages would be unloaded from the transporter, transferred to a vertical concrete storage unit, and moved to a concrete storage pad.

Because the retrieval operations would be essentially the same as the emplacement operations (in reverse), the accident scenarios involving the waste package during operations would bound the retrieval operation. The bounding accident scenario during emplacement would be a transporter runaway and derailment accident in a main drift (see Appendix H, Section H.2.1.4). For above-ground storage accidents, the accident analysis for the continued storage analysis would apply. Recent analyses have found that the only credible accident with the potential for radiological consequences would be an aircraft crash into one of the above-ground storage facilities. However, the aircraft would not penetrate the thickness of the waste package (DIRS 157108-Jason 2001, all).

The analysis assumed that above-ground storage following retrieval would be licensed in compliance with Nuclear Regulatory Commission requirements (10 CFR Part 72). These requirements specify that storage modules must be able to withstand credible accident-initiating events.

4.2.1.2.9 *Noise Impacts from Retrieval*

The analysis in Section 4.1.9 shows that there would be no appreciable noise impacts for the construction, operation and monitoring, and closure phases of repository operations. Noise impacts associated with retrieval would be less than those associated with repository operations because of the reduced scope of activities and the smaller number of workers required. Thus, noise impacts from retrieval operations would be small.

4.2.1.2.10 *Aesthetic Impacts from Retrieval*

Retrieval activities would not be likely to produce adverse impacts on the visual quality of the landscape surrounding Yucca Mountain. Retrieval would essentially be the reverse of emplacement and would use the same types of equipment. Impacts from emplacement would be small. The only difference from the emplacement activities would be the construction of a Waste Retrieval and Storage Area in Midway Valley north of the North Portal Operations Area with a connecting transportation corridor. These activities would occur in the repository area and in Class C scenic quality lands away from the public view and, therefore, would have no impact on the existing visual character of the landscape.

4.2.1.2.11 *Impacts to Utilities, Energy, Materials, and Site Services from Retrieval*

The following sections discuss utility, energy, materials, and site service impacts.

Utilities and Energy. The estimated electric power demand for retrieval would be less than 10 megawatts. This demand would be well within the capacity that would be available at the repository.

The fossil-fuel use estimated for retrieval activities would approach 25 million liters (6.6 million gallons). This consumption level is less than 0.1 percent of the annual consumption in the State of Nevada. In addition, the repository would use about 2 million liters (530,000 gallons) of hydraulic oil and lubricants, which DOE would recycle.

Materials. For the Waste Retrieval and Storage Area, DOE would build a concrete pad and retrieval support facilities. Construction would require about 600,000 cubic meters (780,000 cubic yards) of concrete and 46,000 metric tons (51,000 tons) of steel, which would not affect the regional supply capacity. About 11,000 concrete storage modules would be required. The concrete would be obtained from offsite sources or the onsite batch plant would be used. The storage modules would be relatively simple concrete vessels with a 0.64-centimeter (0.25-inch) steel liner. About 121,000 cubic meters (158,000 cubic yards) of concrete would be required to build 11,000 modules, which probably would be manufactured commercially. Material usage impacts would be small. The impacts of shipping about 11,000 concrete storage modules to the site would be comparable to those for shipping about 11,000 disposal containers to the site (see Chapter 6, Section 6.1.3).

Site Services. The onsite emergency response capability and the security, medical, and fire protection units that would support operations would be available to support retrieval, so no additional impacts would be likely.

Table 4-58 summarizes impacts to utilities, energy, and materials.

Table 4-58. Utilities, energy, and materials for retrieval.[a,b,c]

	Electric		Fossil fuel		Construction materials	
Location	Peak (MW)[d,e]	Use (1,000 MWh)[f]	Liquid fuels (million liters)[g]	Oils (million liters)	Concrete (1,000 cubic meters)[h]	Steel (1,000 metric tons)[i]
Surface	1.3	83	21	0.034	600	46
Subsurface	7.7	700	0.3	2.2	0	0
Totals	***9.0***	***780***	***21.3***	***2.2***	***600***	***46***

a. Sources: DIRS 104508-CRWMS M&O (1999, pp. I-22 to I-24); DIRS 104523-CRWMS M&O (1999, p. 6-35).
b. All entries except peak electric power are cumulative totals for the entire period.
c. Approximate retrieval period would be 14 years.
d. Peak electric power is the peak demand that would occur during the period.
e. MW = megawatts.
f. MWh = megawatt-hours.
g. To convert liters to gallons, multiply by 0.26418.
h. To convert cubic meters to cubic yards, multiply by 1.3079.
i. To convert metric tons to tons, multiply by 1.1023.

4.2.1.2.12 *Impacts to Waste Management from Retrieval*

The construction of the Waste Retrieval and Storage Area would generate an estimated maximum of 13,000 cubic meters (460,000 cubic feet) of construction debris, 2,800 cubic meters (99,000 cubic feet) of sanitary and industrial solid waste, and 520 cubic meters (18,000 cubic feet) of hazardous waste (DIRS 104508-CRWMS M&O 1999, p. I-22). Based on operations generation rates, retrieval of the waste packages would generate an estimated 4,900 cubic meters (170,000 cubic feet) of sanitary and industrial solid waste. Throughout the construction of the retrieval facilities and retrieval operations, the workforce would generate sanitary sewage. After the spent nuclear fuel and high-level radioactive waste were placed in the concrete storage modules and on the concrete storage pads, waste generation would continue due to the presence of a workforce. Surveillance and monitoring activities would generate sanitary and industrial solid and low-level radioactive waste.

Construction debris and sanitary and industrial solid waste would be disposed of at onsite facilities or at the Nevada Test Site. Sanitary sewage would be disposed of at onsite facilities. Low-level radioactive waste would be disposed of at the Nevada Test Site or another government or commercial facility in accordance with applicable Federal and state requirements. Hazardous waste would be shipped off the site for treatment and disposal at a permitted commercial facility. As discussed in Section 4.1.12, the available capacity for hazardous waste treatment and disposal in the western states would exceed the demand. Assuming this trend would continue, hazardous waste possibly generated during retrieval activities would have a very small impact on the capacity for treatment and disposal at commercial facilities.

4.2.1.2.13 *Impacts to Environmental Justice from Retrieval*

Workers at the Yucca Mountain site would be representative of the population mix in the surrounding areas of Nevada. Hence, there would be no disproportionate impacts to minority or low-income workers in the Yucca Mountain region during retrieval activities. Disproportionate impacts to minority or low-income populations from retrieval construction and operation activities would be unlikely. Impacts to areas of cultural importance to American Indians could vary depending on the conduct of activities and the location of significance boundaries.

4.2.2 IMPACTS FROM RECEIPT PRIOR TO THE START OF EMPLACEMENT

Repository operations would begin after DOE received a license from the Nuclear Regulatory Commission to receive and possess spent nuclear fuel and high-level radioactive waste. For this EIS, DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and occur over a 24-year period (70,000 MTHM at approximately 3,000 MTHM per year), unless surface aging was used, in which case there would be a 50-year operations period. The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository as a contingency action, not part of the Proposed Action. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 40,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. In all cases, potential impacts would be bounded by those presented for the lower-temperature operating mode in Section 4.1.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

102043	AIWS 1998	AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.
104926	Bauhaus 1998	Bauhaus, M. 1998. Estimate of 1998 Concrete to be Used in the Las Vegas Area. Telephone conversation from M. Bauhaus to M. Sherwood (Nevada Ready Mix), August 7, 1998, EIS: AR-GEN-35654. ACC: MOL.19990511.0382.
103074	BEA 1992	BEA (Bureau of Economic Analysis) 1992. *Regional Multipliers: A User Handbook for the Regional Input-Output Modeling System (RIMS II).* BEA REA 92-01. 2nd Edition. Washington, D.C.: U.S. Department of Commerce. TIC: 242623.
103075	Bechtel 1997	Bechtel Nevada 1997. *Ecological Monitoring and Compliance Program Fiscal Year 1997 Report.* Las Vegas, Nevada: Bechtel Nevada, Ecological Services. TIC: 243786.
102475	Brussard et al. 1994	Brussard, P.F.; Berry, K.H.; Gilpin, M.E.; Jacobson, E.R.; Morafka, D.J.; Schwalbe, C.R.; Tracy, C.R.; and Vasek, F.C. 1994. *Desert Tortoise (Mojave Population) Recovery Plan.* Portland, Oregon: U.S. Fish and Wildlife Service. TIC: 241399.

4.1.10 AESTHETIC IMPACTS

This section describes potential aesthetic impacts from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. These activities would not cause adverse impacts to aesthetic or visual resources in the region. The analysis of such impacts considered the natural and manmade physical features that give a particular landscape its character and value as an environmental factor. The analysis gave specific consideration to scenic quality, visual sensitivity, and distance from observation points.

Yucca Mountain has visual characteristics fairly common to the region (a scenic quality rating of C), and visibility of the repository site from publicly accessible locations is low or nonexistent. The intervening Striped Hills and the low elevation of the southern end of Yucca Mountain and Busted Butte would obscure the view of repository facilities from the south near the Town of Amargosa Valley, approximately 22 kilometers (14 miles) away. There is no public access to the north or east of the site to enable viewing of the facilities. The only structures that could potentially be visible from the west and exceed the elevation of the southern ridge of Yucca Mountain [1,500 meters (4,900 feet)] would be the ventilation exhaust stacks (numbering 3 to 9) and support structures that could be located along the crest of the mountain. The exhaust stacks could be approximately 15 to 18 meters (50 to 60 feet) high, but a lower profile design could be implemented. The ventilation system would include intake and exhaust stacks, support structures, and access roads. The ventilation system would be constructed and maintained on approximately 105 acres and would include approximately 30 structures (DIRS 153849-DOE 2001, p. 2-33). Some of the exhaust stacks would likely be located along the crest of the mountain, while the intakes would be constructed along the eastern side of the ridge. The height of the ventilation intake structures would be lower than the exhaust stacks and would be constructed at lower elevations. Therefore, the intake stacks would not be as likely to impact the area aesthetically as the exhaust stacks. The presence of exhaust ventilation stacks on the crest of Yucca Mountain could be an aesthetic aggravation to Native Americans.

The intake and exhaust ventilation stacks might be angled, thereby lowering the height of the structure and lessening impact. Recontouring the area in the vicinity of the ventilation system structures and the use of natural vegetation as screening would also lessen potential impact. Because of the height of the ventilation stack structures above Yucca Mountain, the Federal Aviation Administration or the Air Force might require flashing beacon lights atop the stacks. If beacons were required, they could be visible for a great distance, especially west of Yucca Mountain. Closure activities, such as dismantling facilities and reclaiming the site, would improve the visual quality of the landscape. Adverse impacts to the visual quality due to closure would be unlikely.

DOE would provide lighting for operation areas at the repository. This lighting could be visible from public access points, especially from the west due to the ventilation structures atop Yucca Mountain. There would not be significant visual impacts due to repository lighting to users of Death Valley National Park. The towns of Amargosa Valley, Beatty, and Pahrump, located between the park and the repository, probably would cause greater impact to the nightly *viewshed* than operational lighting of the repository. The visual impact of the lighting from Las Vegas would also have significantly more impact in the region than that of the proposed repository. The use of shielded or directional lighting at the repository would limit the amount of light that could be viewed from outside the repository operational area.

As described in Section 4.1.1.2, land disturbance for the operating modes would not differ greatly, ranging from 4.3 to 6.0 square kilometers (1,000 to 1,500 acres), a small fraction of the 600 square kilometers withdrawn for the repository. The aesthetic impacts of the land disturbance resulting from implementation of the Proposed Action design would be temporary.

4.1.11 IMPACTS TO UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to residential water, energy, materials, and site services from performance confirmation, construction, operation and monitoring, and closure activities. The scope of the analysis included electric power use, fossil-fuel and oil and lubricant consumption, consumption of construction materials, and onsite services such as emergency medical support, fire protection, and security and law enforcement. The analysis compared needs to available capacity. The region of influence would include the local, regional, and national supply infrastructure that would have to satisfy the needs. The analysis used engineering estimates of requirements for construction materials, utilities, and energy.

Construction activities would occur during both the construction and the operation and monitoring phases. Table 4-38 lists electric energy, fossil-fuel, and oil and lubricant use during the different phases. Table 4-39 lists construction material use. Both tables list comparative values for the higher-temperature operating mode and a range of values for the lower-temperature operating mode. DOE prorated impacts to site services, if any, with those to the commodity areas to produce an estimate of overall impacts.

Overall, DOE expects only small impacts to residential water, energy, materials, and site services from the Proposed Action. DOE would, however, have to enhance the electric power delivery system to the Yucca Mountain site for the operating modes considered.

4.1.11.1 Impacts to Utilities, Energy, Materials, and Site Services from Preconstruction Testing and Performance Confirmation

DOE would obtain utilities, energy, and materials for preconstruction testing and performance confirmation activities from existing sources and suppliers. Water would come from existing wells. Power would come from regional suppliers to the existing Nevada Test Site transmission system. Based on site characterization activities, these activities would not cause meaningful impacts to regional utility, energy, and material sources. In addition, DOE would continue to use such existing site services as emergency medical support, fire protection, and security and law enforcement (as described in Chapter 3, Section 3.1.11.3) during preconstruction testing and performance confirmation.

4.1.11.2 Impacts to Utilities, Energy, Materials, and Site Services from Construction, Operation and Monitoring, and Closure

Residential Water

Population growth associated with the Proposed Action could affect regional water resources. Based on the information in Section 4.1.6, in 2030 the Proposed Action would result in a maximum population increase of about 6,200 in Clark and Nye Counties. About 80 percent of these people would live in Clark County and about 20 percent in Nye County. Whether domestic water needs were satisfied predominantly from surface-water sources, as is the case for most of Clark County, or from groundwater sources, as for most of Nye County, these relatively small increases in population would have very minor impacts on existing water demands.

The maximum project-related population increase for Clark County would amount to about 0.4 percent of the 2000 population and less than 0.2 percent of the County’s population in 2030 (see Chapter 3, Section 3.1.7). Correspondingly, the associated increase in water demand in the county as a result of the proposed project would be very small. The population of Indian Springs in Clark County would increase by a projected maximum of about 180 as a result of the Proposed Action. This number represents about 14 percent of the 2000 Indian Springs population and, based on a Las Vegas Valley average demand for domestic water of 720 liters (190 gallons) per day per person (DIRS 148196-SNWA 1999, all), would require a quantity of water that is about 9 percent of the community’s quasimunicipal groundwater

Table 4-38. Electricity and fossil-fuel use for the Proposed Action.[a]

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Phase/activity durations (years)		
Construction phase	5	5
Operations and monitoring phase		
Operations	24	24 or 50
Monitoring	76	99 - 300
Closure phase	10	11 - 17
Total	***115***	***171 - 341***[a]
Peak electric power (megawatts)		
Construction phase	25	25
Operations and monitoring phase		
Operations	47	40 - 54
Monitoring	7.7	7.8 - 15
Closure phase	10	10 - 18
Maximum	*47*	*40 - 54*
Electricity use (1,000 megawatt-hours)		
Construction phase	150	190 - 210
Operations and monitoring phase		
Operations	5,200	5,300 - 9,200
Monitoring	4,800	9,700 - 29,000
Closure phase	720	790 - 1,300
Total	***11,000***	***16,000 - 36,000***[a]
Fossil fuel (million liters)		
Construction phase	5.5	5.5 - 6
Operations and monitoring phase		
Operations	360	370 - 500
Monitoring	2.3	2.6 - 13
Closure phase	5.2	5.1 - 6.6
Total	***370***	***380 - 510***[a]
Oils and lubricants (million liters)		
Construction phase	2.6	3.1 - 3.5
Operations and monitoring phase		
Operations	8.5	9.8 - 18
Monitoring	9	13 - 53
Closure phase	2	1.8 - 3
Total	***22***	***33 - 71***[a]

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

withdrawal in 1997 [0.51 million cubic meters (410 acre-feet)] (DIRS 102170-NDCNR 1998, all). DOE expects the population of Indian Springs to be larger by 2030 and on a percentage basis, the contribution (and associated water demand) from project-related growth would be smaller than current numbers. However, this small community would be more likely to be affected by projected growth than other areas in Clark County.

In Nye County, estimates of domestic water demand for 1995 are about 750 liters (200 gallons) per day per person (DIRS 104888-Le Strange 1997, Table 10). At this demand, the project-related increase in Nye County population would result in an additional water demand of about 0.30 million cubic meters (240 acre-feet) of water per year. This represents about 0.3 percent of the water use in Nye County in 1995. As indicated in Section 4.1.6, most (about 92 percent) of the project-related growth in Nye County would occur in Pahrump. This would equate to adding about 0.28 million cubic meters (220 acre-feet) to Pahrump's annual water demand, which represents about 0.9 percent of the 1995 Pahrump water

Table 4-39. Construction material use for the Proposed Action.[a]

Usage	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Phase/activity durations (years)		
Construction phase	5	5
Operations and monitoring phase		
Operations	24	24 or 50
Monitoring	76	99 - 300
Closure phase	10	11 - 17
Total	***115***	***171 - 341***[a]
Concrete (1,000 cubic meters)		
Construction phase	420	490 - 500
Operations and monitoring phase		
Operations	240	350 - 880
Monitoring	0	0
Closure phase	3	3 - 5
Total	***670***	***850 - 1,400***[a]
Cement (1,000 metric tons)		
Construction phase	160	190
Operations and monitoring phase		
Operations	100	150 - 340
Monitoring	0	0
Closure phase	1.2	1.2 - 1.9
Total	***250***	***310 - 530***[a]
Steel (1,000 metric tons)		
Construction phase	100	120
Operations and monitoring phase		
Operations	62	150 - 180
Monitoring	0	0
Closure phase	0.03	0.04
Total	***160***	***270 - 300***[a]
Copper (1,000 metric tons)		
Construction phase	0.2	0.23
Operations and monitoring phase		
Operations	0.08	0.24 - 0.6
Monitoring	0	0
Closure phase	0	0
Total	***0.3***	***0.5 - 0.86***[a]

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

withdrawal of 30 million cubic meters (24,000 acre-feet). By 2030, when the peak population increases would occur, the project-related increase in water demand would be an even smaller percentage of the total Nye County and Pahrump water need. The increase in domestic water demand in Nye County as a result of the proposed project would be very small.

Residential Sewer

Sewer utilities could be affected by population growth associated with the Proposed Action. In Clark County, where most of the population growth would take place, the fact that the maximum project-related population increase would amount to about 0.4 percent of the 2000 population indicates that impacts to the populous areas of the county (that is, the Las Vegas Valley) would be very small. In Indian Springs, where project-related growth would be a more substantial portion of the community population, small treatment facilities designed for a specific area or individual household septic tank systems would accommodate wastewater treatment needs. In either case, the added population would not be likely to cause overloading to a sewer utility.

Growth in Nye Country from the Proposed Action would be likely to occur primarily in the Pahrump area. There is no reason to believe that project-related population increases would overload a sewer utility. Again, small, limited-service treatment facilities or individual septic tank and drainage field systems would provide the primary wastewater treatment capacities.

Electric Power

During the construction phase, the demand for electricity would increase as DOE operated two or three tunnel boring machines and other electrically powered equipment. The tunnel boring machines would account for more than half of the demand for electricity during the construction phase. The estimated peak demand for electric power during the construction phase would be about 25 megawatts with use varying between about 150,000 and 210,000 megawatt-hours, depending on the operating mode. Excavation activities for the operating modes would use two or three tunnel boring machines. However, the operations time would increase for the lower-temperature operating mode because of the increased tunnel lengths.

As discussed in Chapter 3, Section 3.1.11.2, the current electric power supply line has a peak capacity of only 10 megawatts. DOE, therefore, is evaluating modifications and upgrades to the site electrical system, as discussed below, under Repository Electric Power Supply Options.

During the operations period, the development of emplacement drifts would continue in parallel with emplacement activities. During this period, the peak electric power demand would be between 40 and 54 megawatts, depending on the operating mode.

Following the completion of excavation activities, the demand for electric power would drop to about 21 to 34 megawatts and would continue to decrease, following the completion of emplacement and decontamination activities, to less than 15 megawatts for monitoring and maintenance activities. The closure phase would last from 10 to 17 years, depending on the operating mode. The peak electric power demand would be less than 18 megawatts for either of the operating modes during closure.

The repository demand for electricity would be well within the expected regional capacity for power generation. Nevada Power Company, for example, experienced a growth in peak demand of nearly 30 percent from 1993 to 1997 and has demonstrated the ability to meet customer demand in this high-growth environment through effective planning (DIRS 103284-Vogel 1998, all). Nevada Power's current planning indicates that it intends to maintain a reserve capacity of 12 percent. In 2010, at the beginning of the operation and monitoring phase, Nevada Power projects a net peak load of 5,950 megawatts and is planning a reserve of 714 megawatts (DIRS 103413-NPC 1997, Figures 2 and 4). The maximum 54-megawatt demand that the repository would require would be less than 1 percent of the projected peak demand in 2010, and less than 8 percent of the planned reserve. While the accuracy and viability of long-term planning for electrical power demand is now more uncertain than in previous years, DOE expects that regional capacity planning would accommodate the future repository demand.

Repository Electric Power Supply Options

As discussed above, the estimated repository electric power demand would exceed the current electric distribution capacity to the site after construction began in 2005. DOE would have to increase the electric power capacity to the site to accommodate the initial demand of about 25 megawatts during the construction phase and to support the estimated peak demand of as much as 54 megawatts during the operations period. A range of options including a modification or upgrade of the existing transmission and distribution system is under consideration to meet the repository electricity demand (DIRS 102045-CRWMS M&O 1998, all). DOE eliminated consideration of onsite generation of electricity in conjunction with the onsite plant that would generate steam for heating because the steam plant would be much smaller than a plant needed for power generation. DOE would, however, construct and operate a solar power generating facility close to the North Portal to support repository operations. The solar facility, which could produce as much as 3 megawatts of power, would be a dual-purpose facility, serving as a demonstration of photovoltaic power generation and augmenting the overall repository electric power supply (as much as 7 percent). In addition, DOE would also investigate using power supplied from a 436-megawatt wind farm proposed for the Nevada Test Site. This private-sector enterprise is currently being evaluated and has been described in a recent draft environmental assessment (DIRS 154545-DOE 2001, all). DOE has issued a Notice of Intent to prepare an environmental impact statement for this project (66 *FR* 38650; July 25, 2001). Other onsite generation capacity would use diesel-powered generators for emergency equipment.

As discussed in Chapter 3, Section 3.1.11.2, the repository site receives electricity through a feeder line from the Canyon Substation, which is rated at 69 kilovolts and has a capacity of 10 megawatts. The minimum modification would be to upgrade this line to 40 to 54 megawatts, modify the Nevada Test Site power loop to support repository operations in conjunction with other Test Site activities, and upgrade utility feeder lines to the Nevada Test Site. The existing Nevada Test Site power loop has a rated capacity of about 72 megawatts, but preliminary analysis of loop performance with a typical repository load (about 40 megawatts) indicated that unacceptable voltage reductions could occur at some Test Site locations. The minimum modification to the power loop to reduce the potential for unacceptable voltage reductions would be to install capacitors in the loop. Other options to obtain satisfactory performance for the power loop would include upgrading sections of the loop and the utility-owned feeder lines to the loop. Additional options, which would be variations of this approach, would include providing upgraded power lines directly from the utilities to the repository site.

As discussed in Chapter 3, Section 3.1.11.2, two commercial utility companies supply electricity to the Nevada Test Site feeder lines that power the Test Site power loop. Nevada Power Company owns and operates a 138-kilovolt line from the Las Vegas area to the Mercury Switching Station on the Test Site. Valley Electric Association owns and operates 138- and 230-kilovolt lines from the Las Vegas area to Pahrump and a 138-kilovolt line from Pahrump to the Jackass Flats substation on the Test Site near Amargosa Valley. The options DOE is evaluating include upgrading either or both of these lines. The options also include connecting both utility feeder lines directly to the repository with new 138- or 230-kilovolt lines to either the North or South Portal to obtain independent redundant power capability. DOE has considered constructing a new power line from the Tonopah/Anaconda area to near the Town of Amargosa Valley through Beatty with a direct tie to the South Portal at the repository. All system modifications would include appropriate modifications to transformers and switchgear. The approach in all cases would be to use existing power corridors where possible to limit environmental impacts and to reduce the need for additional rights-of-way. Depending on the option chosen, National Environmental Policy Act analysis would be conducted, as appropriate.

Fossil Fuels

Fossil fuels used during the construction phase would include diesel fuel and fuel oil. Diesel fuel would be used primarily to operate surface construction equipment and equipment to maintain the excavated rock pile. Fuel oil would fire a steam plant at the North Portal, which would provide building and process heat for the North Portal Operations Area. During construction the estimated use of diesel fuel and fuel oil would be 5.5 million to 6.0 million liters (1.5 million to 1.6 million gallons). The regional supply capacity of gasoline and diesel fuel is about 3.8 billion liters (1 billion gallons) per year for the State of Nevada, based on motor fuel use (DIRS 148094-BTS 1997, all). About half of the State total is consumed in the three-county region of influence (Clark, Lincoln, and Nye Counties) with the highest consumption in Clark County, so yearly repository use during the construction phase would be less than 1 percent of the current regional consumption.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It would range between about 370 million and 500 million liters (about 98 million and 130 million gallons) depending on the repository operating mode. The annual use would be highest during the operations period and would decrease substantially during the monitoring period. The projected use of liquid fossil fuels would be within the regional supply capacity and would cause little impact. As discussed above, motor fuel use in the State of Nevada in 1996 was about 3.8 billion liters (1 billion gallons) (DIRS 148094-BTS 1997, all), which provides the baseline for the regional supply capacity. The highest annual use during the operations period would be less than 0.5 percent of the 1996 capacity in Clark, Lincoln, and Nye Counties.

During the closure phase, fossil-fuel use would be between 5.1 million and 6.6 million liters (1.3 million and 1.7 million gallons), depending on the repository operating mode. Use during the closure phase would be similar to that for the construction phase.

Hydraulic oils and lubricants and non-fuel hydrocarbons would be used to support operation of equipment during all phases of the project. The quantities of these materials used would range from about 20 million to about 70 million liters (5.3 and 18 million gallons). Because these materials would be recycled and reused, they are not considered in terms of impacts to the environment.

Construction Material

The primary materials needed to construct the repository would be concrete, steel, and copper. Concrete, which consists of cement, sand, aggregate and water, would be used for liners in the main tunnels and ventilation shafts in the subsurface and for the construction of the surface facilities. Aggregate available in the region would be used for concrete and cement would be purchased regionally. The amounts of concrete and cement required are listed in Table 4-39. During the construction phase the amount of concrete required would range from about 420,000 to 500,000 cubic meters (about 550,000 to 650,000 cubic yards), depending on the repository operating mode. For this phase, as much as about 120,000 metric tons (130,000 tons) of steel would be required for a variety of uses including rebar, piping, vent ducts, and track, and 200 to 230 metric tons (220 to 250 tons) of copper for electrical cables. Because the subsurface configuration of the repository would differ for the different operating modes, the relative amount of material used during the initial 5-year construction phase might not be indicative of the amount required to complete the subsurface through the end of development. For example, the amount of steel used during the construction phase for the range of operating modes would be about the same, but the total amount of steel used for the lower-temperature operating mode would be almost twice the amount that would be used for the higher-temperature operating mode.

For the lower-temperature operating mode, which would require the most concrete, the average yearly concrete demand for the construction phase would be about 100,000 cubic meters (about 130,000 cubic yards). The required quantity of concrete would not be expected to affect the regional supply system, which has been able to support the robust construction environment in Las Vegas. The quantities of cement required for the concrete are listed in Table 4-39 because this material would be purchased through regional markets and trucked to the site. This quantity of cement represents less than about 3 percent of the cement consumed in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all).

Because the markets for steel and copper are worldwide in scope, DOE expects little or no impact from increased demand for steel and copper in the region.

The closure phase would require an estimated maximum of 5,000 cubic meters (6,500 cubic yards) of concrete and an estimated maximum of 40 metric tons (44 tons) of steel.

Overall Comparative Impacts

The overall impacts of the repository project in the areas of utilities, energy, and construction material can be compared by evaluating the quantities of these commodities that would be consumed over the life of the project. In general, the quantities of utilities, energy, and materials consumed over the life of the project would be small in comparison to the regional supply capacity, and would be unlikely to affect regional supplies or prices. A major reason for low impacts is the proposed repository schedule for most activities would extend over decades. Even though DOE would build a solar power generating facility on the repository site, it would be necessary to upgrade the transmission lines to the site for the repository to obtain adequate electric power for all the scenarios considered.

Site Services

During the construction phase, DOE would rely on the existing support infrastructure described in Chapter 3, Section 3.1.11.3, during an emergency at the repository. DOE would maintain these capabilities until the project could provide its own services on the site.

The primary onsite response would occur through the onsite Fire Station, Medical Center, and Health Physics facilities after their construction at the North Portal was complete. The Fire Station would maintain fire and rescue vehicles, equipment, and trained professionals to respond to fires, including radiological, mining, industrial, and accident events at the surface and subsurface. The Medical Center would be adjacent to the Fire Station, and would maintain a full-time doctor and nurse and medical supplies to treat emergency injuries and illnesses. These facilities would have the capability to provide complete response to most onsite emergencies. DOE would coordinate the operation of these facilities with facilities at the Nevada Test Site and in the surrounding area to increase response capability, if necessary.

A site security and safeguards system would include the surveillance and safeguards functions required to protect the repository from unauthorized intrusion and sabotage. The system would include the site security barriers, gates, and badging and automated surveillance systems operated by trained security officers. Support for repository security would be available from the Nevada Test Site security force and the Nye County Sheriff's Department, if needed.

The emergency response system would provide responses to accident conditions at or near the repository site. The system would maintain emergency and rescue equipment, communications, facilities, and trained professionals to respond to fire, radiological, mining, industrial, and general accidents above or below ground.

The planned onsite emergency facilities should be able to respond to and mitigate most onsite incidents, including underground incidents, without outside support. Therefore, there would be no meaningful impact to the emergency facilities of surrounding communities or counties.

4.1.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

This section describes the management of the radioactive and nonradioactive waste that DOE would generate as a result of performance confirmation, construction, operation and monitoring, and closure activities. The range of operating modes would generate different quantities of waste.

The evaluation of waste management impacts considered the quantities of nonhazardous industrial, sanitary, hazardous, mixed, and radioactive wastes that repository-related activities would generate. Estimated waste quantities are presented in Tables 4-40 through 4-44 in Sections 4.1.12.2 and 4.1.12.4. These estimates were based on construction and operating experience, engineering data, water use estimates, material use estimates, and number of workers. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes.

4.1.12.1 Waste and Materials Impacts from Preconstruction Testing and Performance Confirmation

DOE expects preconstruction testing and performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal quantities (DIRS 104508-CRWMS M&O 1999, p. 17). Based on 1997 waste generation reports, preconstruction testing and performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (DIRS 104952-Sygitowicz 1998, pp. 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (DIRS 104882-Harris 1998, pp. 3 through 6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression, rinsewater from concrete production and transport, and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

4.1.5.2 Impacts to Cultural Resources from Construction, Operation and Monitoring, and Closure

Impacts to archaeological and historic sites could occur during the initial construction phase and the operation and monitoring phase, when ground-disturbing activities would take place. Indirect impacts to archaeological and historic sites could occur during all phases of the Proposed Action.

Archaeological and Historic Resources

Potential impacts to *National Register*-eligible cultural resources from surface facility construction could occur in areas where ground-disturbing activities would take place. Repository development would disturb a maximum of about 4.5 square kilometers (1,100 acres) of previously undisturbed land at the site.

Archaeological investigations conducted in the immediate vicinity of the proposed surface facilities in support of previous and ongoing characterization studies and infrastructure construction have identified about 830 archaeological and historic sites. These investigations have identified resource localities and provided mitigative relief for resources potentially subject to direct impacts (DIRS 104997-CRWMS M&O 1999, Table 2). In addition, ground-disturbing activities associated with potential nearby project actions (for example, upgrades to utility and road rights-of-way, rail access facilities, excavated rock and other onsite storage areas) would occur in areas that had undergone field inventories and evaluations of cultural resources.

Several known archaeological sites in the vicinity of Midway Valley could be affected by ground-disturbing activities associated with the construction of the surface aging facility. An archaeological site occupies much of Midway Valley, including the general location of the proposed surface aging facility. This site was partially mitigated during site characterization activities in 1991 (DIRS 153162-Buck, Amick, and Hartwell 1994, all). In addition, intensive mitigation efforts were conducted at a nearby archaeological site in 1993, yielding nearly 25,000 artifacts (DIRS 153167-Buck et al. 1998, all). Other known archaeological sites occur in the vicinity of the possible location of the solar power generating facility. These sites have not been evaluated beyond field recording, some having been identified more than 20 years ago. One or more of these sites could be affected by construction at the primary location for the solar power generating facility, as well as such features as access roads and transmission cables.

Increases in both surface activities and numbers of workers at the repository site could increase the potential for indirect impacts at archaeological sites near repository surface facilities. Preliminary results from the monitoring of archaeological sites in the vicinity of Yucca Mountain activities since 1991 indicate that human activities and increased access could result in harmful effects, both intentional and inadvertent, to these fragile resources (DIRS 104997-CRWMS M&O 1999, Chapter 1). Indirect impacts are difficult to quantify and control, but they can include loss of surface artifacts due to illicit collection and inadvertent destruction (DIRS 104997-CRWMS M&O 1999, Chapter 1).

Even though there could be some indirect adverse impacts, the overall effect of the repository on the long-term preservation of the archaeological and historic sites in the analyzed land withdrawal area would be beneficial. Cultural resources in the area would be protected from most human intrusion.

Excavation activities at the repository site could unearth additional materials and features in areas that past archaeological surveys have examined only at the surface. Past surveys in the Yucca Mountain area indicated buried cultural materials at some sites with surface artifacts (DIRS 104997-CRWMS M&O 1999, Chapter 1). Thus, excavation activities could unearth previously undetected subsurface features or artifacts. If this happened, work would stop until a cultural resource specialist evaluated the importance of the discovery.

Native American Viewpoints

DOE would continue the existing Native American Interaction Program (see Chapter 3, Section 3.1.6.2) throughout the Proposed Action. This program promotes a government-to-government relationship with associated tribes and organizations. Continuation of this program during the Proposed Action would enhance the protection of archaeological sites and cultural items important to Native Americans.

The Native American view of resource management and preservation is holistic in its definition of "cultural resource," incorporating all elements of the natural and physical environment in an interrelated context. Moreover, this view includes little or no differentiation between types of impacts (direct versus indirect), but considers all impacts to be adverse and immune to mitigation. Section 4.1.13.4 contains an environmental justice discussion of a Native American viewpoint on the Proposed Action.

Previous studies (DIRS 103465-Stoffle et al. 1990, all; DIRS 102043-AIWS 1998, all) have delineated several Native American sites, areas, and resources in or immediately adjacent to the analyzed land withdrawal area. Construction activities for repository surface facilities would have no direct impacts on these locations. However, because of the general level of importance attributed to these places by Native Americans, and because they are parts of an equally important integrated cultural landscape, Native Americans consider the intrusive nature of the repository to be an adverse impact to all elements of the natural and physical environment (DIRS 102043-AIWS 1998, Chapter 2). In their view, the establishment of the protected area boundary and construction of the repository would continue to restrict the free access of Native American people to these areas. On the other hand, the Consolidated Group of Tribes and Organizations has recognized that past restrictions on public access due to site characterization have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (DIRS 102043-AIWS 1998, Chapter 2).

The potential for indirect impacts from construction activities and more workers in the area would increase, particularly to the physical evidence of past use of the cultural landscape (artifacts, cultural features, archaeological sites, etc.) important to Native American people. DOE would continue to provide training to workers to minimize the potential for indirect impacts.

Eventual closure of the repository would have the beneficial effect of returning much of the disturbed landscape to a natural setting. Some additional impacts could occur to resources or areas important to Native Americans if changes in land status or management that occurred after closure led to increased access by the public. The presence of a permanently entombed repository would represent an intrusion into what Native Americans consider an important cultural and spiritual place. Long-term monitoring features or activities would continue to affect these cultural viewpoints.

4.1.6 SOCIOECONOMIC IMPACTS

This section describes potential socioeconomic impacts from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. Evaluations of the socioeconomic environment in communities near the proposed repository site considered changes to employment, economic measures, population, housing, and some public services. The evaluation used the Regional Economic Models, Inc. (REMI) model to estimate baseline socioeconomic conditions and to estimate economic and population changes caused by the Proposed Action. The potential for changes in the socioeconomic environment would be greatest in the Yucca Mountain region of influence where most of the repository workers would live. As discussed in Chapter 3, Section 3.1.7, this region of influence consists of Clark, Lincoln, and Nye Counties in southern Nevada.

DOE examined the maximum potential employment levels that would be required to implement the range of operating modes. The analysis did not project baseline population or employment in the region of influence beyond 2035 because of the speculative nature of such a forecast.

The discussion in this section of changes to population, employment, Gross Regional Product, real disposable income, and expenditures by the State of Nevada and local governments resulting from the Proposed Action are the deviations from a projected baseline for each parameter. This baseline utilizes data DOE received from the State and local governments. Chapter 3, Section 3.1.7 discusses this baseline.

DOE has considered suggestions made in public comments that the EIS include analysis of possible impacts of perceptions associated with the proposed repository. DOE has determined that it could not quantify any potential impacts resulting from such perceptions and that further research would be unlikely to make quantification possible. From a qualitative standpoint, adverse impacts from perceptions of the repository would be unlikely, absent a large accident or a continuing series of smaller accidents. Section 2.5.4 discusses the reasons for DOE's determination.

4.1.6.1 Socioeconomic Impacts from Preconstruction Testing and Performance Confirmation

The level of employment for preconstruction testing and performance confirmation activities would be similar to or less than the current level of employment for site characterization, as described in Chapter 3, Section 3.1.7. Because population and employment changes between ongoing site characterization activities and future performance confirmation activities would be minimal, there would be no meaningful impacts to housing or public services, including impacts to schools.

4.1.6.2 Socioeconomic Impacts from Construction, Operation and Monitoring, and Closure

4.1.6.2.1 *Impacts to Employment*

> **TERMS RELATED TO EMPLOYMENT**
>
> **Direct Employment:** Jobs expressly associated with project activity.
>
> **Indirect Employment:** Jobs created as a result of expenditures by directly employed project workers (for example, restaurant workers or child care providers) or jobs created by the project-related purchase of goods and services (for example, sales manager of a concrete supply store).
>
> **Composite Employment:** Sum of direct and indirect jobs.

In 2006, the peak year of employment during the initial construction phase, about 1,900 additional workers would also be employed on the Yucca Mountain Repository Project. Figure 4-2 shows composite (direct and indirect) employment changes caused by construction activities, by place of residence during this phase. Incremental employment increases during the construction phase attributable to the repository would peak in 2006 with the addition of about 3,400 workers to the region of influence. This would increase overall employment in the region of influence from the projected baseline (employment without the repository project) of approximately 942,000 jobs to slightly less than 945,000 positions, a change of approximately 0.36 percent. Table 4-14 summarizes repository peak year employment during the initial construction period by place of residence in selected communities. Table 4-15 lists the expected residential distribution of directly employed construction workers over the primary construction phase. These tables do not list Lincoln County because, historically, very few Yucca Mountain Project workers have resided in the County. DOE expects that few, if any, repository employees would live in Lincoln County given the long commute.

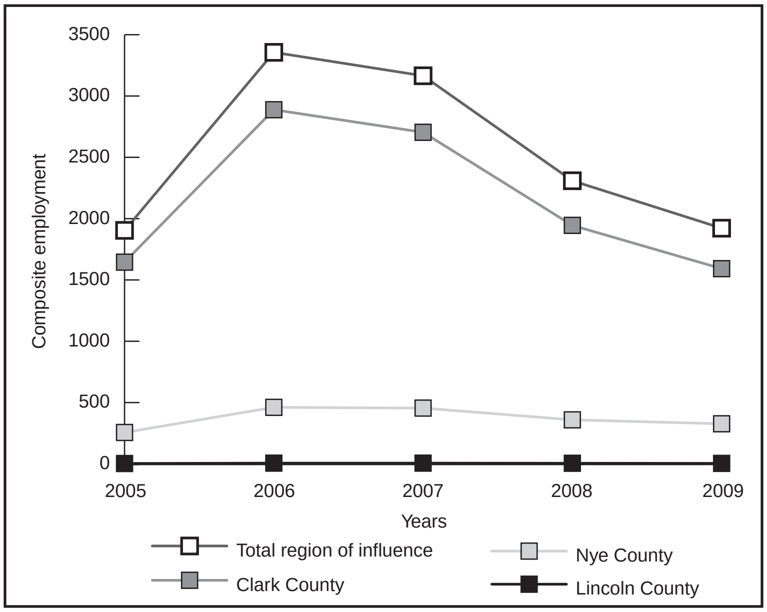


Figure 4-2. Increases in regional composite employment by place of residence during construction phase.

Table 4-14. Expected peak year (2006) increase in construction employment by place of residence in selected communities in Nye and Clark Counties.[a,b,c]

Location	Direct jobs[d]	Indirect jobs[d]	Total jobs[d]
Clark County			
Indian Springs	60	40	100
Rest of Clark County	1,440	1,360	2,800
Clark subtotals	*1,500*	*1,400*	*2,900*
Nye County			
Amargosa Valley	20	10	30
Beatty	3	2	5
Pahrump area	340	90	430
Nye subtotals	*360*	*100*	*460*
Totals[e]	***1,860***	***1,500***	***3,360***

a. Employment and population impacts distributed using residential patterns of Nevada Test Site and Yucca Mountain employees from DOE (DIRS 155987-DOE 2001, all).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County; includes approximately 5 indirect jobs in Lincoln County.
c. Employment in 2006 does not include approximately 220 current workers.
d. Numbers have been rounded to the nearest 10.
e. Totals might not equal sums of values due to rounding.

Table 4-15. Repository direct employment during construction phase by expected county of residence: 2005 to 2009.[a,b,c,d]

County	2005	2006	2007	2008	2009
Clark	1,000	1,660	1,660	1,360	1,300
Nye	240	410	400	330	320
Totals[e]	**1,240**	**2,070**	**2,060**	**1,700**	**1,610**

a. Sources: DIRS 104508-CRWMS M&O (1999, Section 6); DIRS 104523-CRWMS M&O (1999, Section 6).
b. DOE anticipates approximately 80 percent of repository workers would live in Clark County and approximately 20 percent in Nye County.
c. Includes approximately 220 current workers.
d. Numbers are rounded to the nearest 10.
e. Totals might not equal sums of values due to rounding.

Training of operational personnel would begin in 2009. In 2010, direct operational employment would start to increase. Direct operational peak employment would occur in 2012 (with about 2,150 workers). Employment after 2012 would be essentially stable with an average annual workforce of about 1,900 through the year 2033 when operations would be completed.

At the start of the monitoring period, a workforce of up to 1,160 workers would be involved in decontamination of surface facilities for a period of approximately 3 years. The impact to employment from the decontamination activities would be less than 1 percent of the estimated baseline. Figure 4-3 reflects this short-term increase. After decontamination was completed, direct employment would decrease substantially for the remainder of the monitoring period.

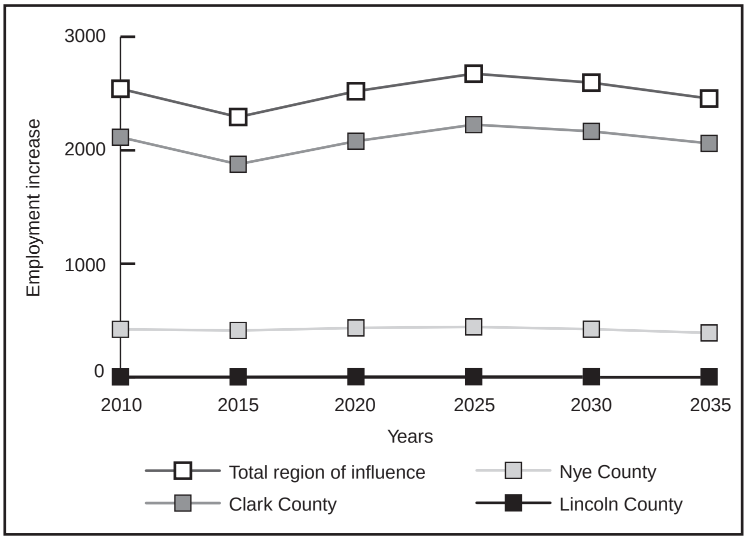


Figure 4-3. Changes in regional employment from operations period and decontamination activities.

Table 4-16 lists the expected residential distribution of repository workers in the peak year of employment (2012) during the operations period. The table also lists the estimated number of indirect jobs created in these communities during 2012. The direct and indirect employment in the region of influence would peak with the addition of approximately 2,700 workers. This would result in an incremental increase of employment from the estimated baseline of about 1,029,000 jobs to about 1,031,000 jobs, a change of less than 0.26 percent from the estimated employment baseline.

Table 4-17 summarizes direct repository employment through the first 24 years of the operation and monitoring phase by county of residence. This table does not list Lincoln County because, historically, so few workers have resided in the County. Figure 4-3 shows the direct and indirect regional employment differences between the bounding employment case for the lower-temperature operating mode with aging and the estimated baseline.

Monitoring and maintenance activities would start with the first emplacement of waste package and would continue through repository closure. DOE estimates that a workforce of approximately 120 workers would be needed to monitor and maintain the repository. Given the expected economic growth in the region of influence, the region could readily absorb declines in repository employment.

To bound this study, the socioeconomic analysis assumes that closure would begin 100 years after the start (and 76 years after the completion) of emplacement activities. The lower-temperature operating mode would require a longer monitoring period, ranging from 125 to 300 years. Therefore, this analysis evaluated potential impacts of a closure of the repository in the lower-temperature mode after as many as

Table 4-16. Expected peak year (2012) increases in operations period employment in selected communities in Clark and Nye Counties.[a]

Location	Direct jobs[b]	Indirect jobs	Total jobs
Clark County			
Indian Springs	70	20	90
Rest of Clark County	1,490	620	2,110
Clark subtotals	*1,560*	*640*	*2,200*
Nye County			
Amargosa Valley	20	10	30
Beatty	3	0	3
Pahrump area	350	70	420
Nye subtotals	*380*	*80*	*460*
Totals[c]	***1,940***	***720[d]***	***2,660***

a. Numbers have been rounded to the nearest 10.
b. Employment in 2012 does not include approximately 220 current workers.
c. Totals might not equal sums of values due to rounding.
d. Includes 4 indirect workers in Lincoln County.

Table 4-17. Repository direct employment during operations period and decontamination activities by county of residence: 2010 to 2035.[a,b,c]

County	2010	2015	2020	2025	2030	2035[d]
Clark total	1,630	1,600	1,650	1,640	1,560	1,420
Nye total	400	390	400	400	380	350
Totals[c]	***2,030***	***1,990***	***2,050***	***2,040***	***1,940***	***1,770***

a. Includes approximately 220 current workers.
b. Numbers have been rounded to the nearest 10.
c. Totals might not equal sums of values due to rounding.
d. Year 2035 shows the short-term (3-year) impact of decontamination activities.

324 years of operation and monitoring. Employment would be far less than the peak during the operation and monitoring phase and, therefore, would be unlikely to generate employment changes and economic measures of more than one-half of 1 percent. There probably would be no perceptible repository-induced changes to baseline employment in the region of influence. Regional impacts to socioeconomic parameters during the closure phase would be small.

4.1.6.2.2 *Impacts to Population*

From 2010 through 2035 the projected regional population will grow from about 1.9 million residents to approximately 2.8 million. The peak year population contribution attributable to the repository would be approximately 6,200 people, or approximately 0.24 percent of the region of influence's estimated population baseline of 2.6 million people in 2030. As a result, the Yucca Mountain Repository Project would have only small effects on the population growth in the region of influence. Figure 4-4 shows the projected population increase resulting from the repository project.

Table 4-18 lists estimated incremental population increases that would occur as a result of repository activities in Clark and Nye Counties based on historic Nevada Test Site residential distribution patterns. As mentioned above, repository workers would be unlikely to reside in Lincoln County. The incremental peak population increase in Clark County would be less than 0.21 percent.

Population growth associated with the repository would be more evident in Nye County. The County's population increase would be approximately 1.4 percent of the projected population of 77,000, for the County in 2030, the peak year for potential repository population impacts.

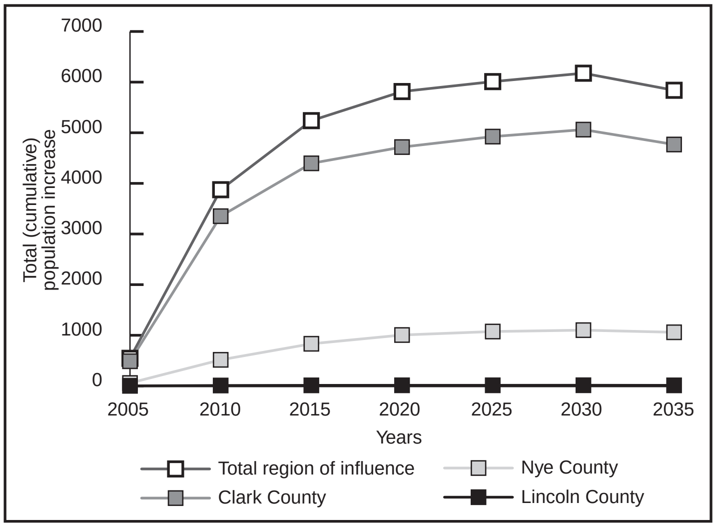


Figure 4-4. Regional population increases from construction and operations: 2005 to 2035.

Table 4-18. Maximum expected population increase from Proposed Action (2030).[a,b]

Location	Population increase
Clark County	
Indian Springs	180
Rest of Clark County	4,880
Clark total	***5,060***
Nye County	
Amargosa Valley	80
Beatty	10
Pahrump	1,000
Nye total	***1,100***

a. Numbers have been rounded to the nearest 10.
b. Totals might not equal sums of values due to rounding.

4.1.6.2.3 *Impacts to Economic Measures*

Table 4-19 lists estimated changes in economic measures that would result from repository activities during the construction phase (values are expressed in 2001 dollars). Increases in real disposable income within the region of influence would peak in 2007 with an increase of about $110 million, while increases in Gross Regional Product would peak in 2006 at about $160 million. Regional expenditures by State and local governments would peak at $11 million in 2009. Economic measures for the region of influence would increase by less than one-third of 1 percent over the projected baseline (estimated economic measures without the repository project).

Table 4-20 lists the changes in economic measures that would result from the repository project duringthe operations period. Increases in Gross Regional Product would peak in 2029 at about $125 million. Increases in real disposable income would peak in 2029 at $149 million. Increases in regional expenditures by State and local governments under the maximum employment case would peak in 2030 at about $22 million. Economic measures for the region of influence would increase by less than 0.5 percent over the projected baseline.

GROSS REGIONAL PRODUCT

The value of all final goods and services produced in the region of influence.

4.1.6.2.4 Impacts to Housing

Given the size of the regional employment, the number of workers in-migrating to work on the repository would be relatively small. Because the inmigration would be small, the increased demand for housing would also be small.

Table 4-19. Increases in economic measures within the region of influence from repository construction: 2005 to 2009 (millions of dollars).[a]

Jurisdiction	2005	2006	2007	2008	2009
Clark County					
Disposable income	54	100	103	85	77
Gross Regional Product	80	142	136	100	73
State and local government expenditures	1.5	4.8	7.6	9.1	9.9
Nye County					
Disposable income	3.7	6.7	6.8	5.7	5.9
Gross Regional Product	10	19	18	15	12
State and local government expenditures	0.2	0.5	0.9	1	1.3
Lincoln County					
Disposable income	0.1	0.3	0.3	0.2	0.2
Gross Regional Product	0.1	0.2	0.2	0.2	0.1
State and local government expenditures	0	0	0.1	0.1	0.1
Total region of influence[b]					
Disposable income	58	108	110	90	83
Gross Regional Product	90	160	155	115	85
State and local government expenditures	1.7	5.3	8.5	10	11

a. Numbers are expressed in 2001 dollars.
b. Totals might differ from sums of values due to rounding.

Table 4-20. Increases in economic measures within the region of influence from emplacement and development activities: 2010 to 2033 (millions of dollars).[a]

Jurisdiction	2010	2015	2020	2025	2030	2033
Clark County						
Disposable income	97	104	119	129	133	110
Gross Regional Product	90	82	96	106	105	69
State and local government expenditures	11	15	16.7	18	18	17
Nye County						
Disposable income	8.2	11	13	14	15	14
Gross Regional Product	15	15	16	17	17	12
State and local government expenditures	1.6	2.6	3.2	3.5	3.7	3.6
Lincoln County						
Disposable income	0.3	0.3	0.3	0.4	0.4	0.3
Gross Regional Product	0.2	0.2	0.2	0.2	0.2	0.2
State and local government expenditures	0.1	0.1	0.1	0.1	0.1	0.1
Total region of influence[b]						
Disposable income	106	115	132	144	149	124
Gross Regional Product	104	97	113	123	122	81
State and local government expenditures	12	18	20	21	22	21

a. Numbers are expressed in 2001 dollars.
b. Totals might differ from sums of values due to rounding.

The impact to housing would be minimal because (a) the expected increase in population is so small, (b) the demand is expected to be concentrated in a metropolitan area (Clark County), (c) there are no municipal or state growth control measures that limit housing development, and (d) the region of influence has an adequate supply of undeveloped land to meet expected future demands. Southern Nye County, particularly Pahrump, would experience some demand for housing. In Lincoln County, little or no demand for housing resulting from repository activities would be likely, so housing availability would not be an issue.

During the 1990s and early 21st century, the Bureau of Land Management has conducted land exchanges in Nevada. These exchanges have typically involved a trade of environmentally sensitive land outside Clark County for Bureau land in the County. The land in Clark County moves to the private sector for sale to land developers, particularly developers of large master-planned, densely occupied communities. The land swap policy has helped to accommodate population growth in the greater Las Vegas area.

4.1.6.2.5 Impacts to Public Services

Repository-generated impacts to public services from population changes in the region of influence would be small. Population changes in the region from the maximum repository-related employment case would be a small fraction of the anticipated population growth in the region. Even without the addition of repository jobs, the annual regional growth rate would increase by an estimated 2 to 4 percent, minimizing a possible need to alter plans already in place to meet projected growth.

As mentioned above, the majority of inmigrating workers would likely live in the many communities of Clark County, thereby dispersing the increased demand for public services, including schools. Southern Nye County, particularly Pahrump, also would experience an increased demand for public services. However, because the changes in population (about 1,100 residents in the peak year) would occur steadily over a long period, the County would be able to absorb increased demands in education, law enforcement, and fire protection. Repository-generated impacts to public services would be unlikely in Lincoln County.

4.1.6.3 Summary of Socioeconomic Impacts

The potential socioeconomic impacts associated with repository activities are summarized in this section. For all five socioeconomic parameters evaluated over construction, operations, and decontamination activities, the impacts would be very small, less than 1 percent of the baselines for the region of influence. The construction phase would experience greater impacts for employment, Gross Regional Product, and real disposable income. The operations and decontamination activities would cause the greater impact from increases in population and government spending.

The lower-temperature operating mode and the higher-temperature operating mode would have similar potential impacts. Composite employment, which includes workers directly associated with the construction activity and other indirect workers (food service providers and auto mechanics for example), would peak in 2006. The increase of 3,400 workers represents a 0.36 percent increase to the expected baseline. Gross Regional Product would also peak in 2006 as various goods and services associated with the construction activities were consumed. The expected increase in Gross Regional Product for 2006 is about $160 million, (all values for economic parameters are expressed in 2001 dollars) or 0.31 percent of the baseline. Peak years for the other socioeconomic impacts would be delayed until the operations period. Population increases caused by the increased employment opportunities would peak in 2030, at about 6,200 or less than 0.25 of a percent of the baseline for the year. Government spending would peak in 2030 at $22 million or 0.22 percent of the baseline. Disposable income would also be highest during the operations period, peaking in 2029 at $149 million, or 0.23 percent of the baseline. Impacts during the subsequent decontamination activities, monitoring period, and closure phase would be similar to or smaller than the impacts summarized above.

4.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY IMPACTS

This section describes potential health and safety impacts to workers (occupational impacts) and to members of the public from preconstruction testing and performance confirmation, construction, operation and monitoring, and closure activities. The analysis estimated health and safety impacts separately for involved workers and noninvolved workers for each repository phase. Involved workers are craft and operations personnel who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, aging, and emplacement of spent nuclear fuel and high-level radioactive waste materials; maintenance of the solar power facility; monitoring of the condition and performance of the waste packages; and eventual closure of the repository. Noninvolved workers are managerial, technical, supervisory, and administrative personnel who would not be directly involved in the above activities. This section describes impacts from the receipt of uncanistered spent nuclear fuel. Impacts for canistered fuel would be smaller, as reported in Appendix F, Section F.2.

The types of potential health and safety impacts to repository workers include those from industrial hazards common to the workplace, those from exposure to naturally occurring and manmade radiation and radioactive materials present in the workplace, and those from exposure to naturally occurring nonradioactive airborne hazardous material. Members of the public could be exposed to airborne releases of naturally occurring and manmade radionuclides and naturally occurring hazardous materials. Estimates of human health impacts to members of the public are based on information presented in Section 4.1.2.

Appendix F describes the methodology, data, and data sources used for the calculations of health and safety impacts to workers and supporting detailed results. It also contains a human health impacts primer.

4.1.7.1 Impacts to Occupational and Public Health and Safety from Preconstruction Testing and Performance Confirmation

Preconstruction testing and performance confirmation activities would be similar to the activities performed during Yucca Mountain site characterization. Their purpose would be to ensure that systems, operations, and materials were functioning as predicted. These activities could include the construction of surface facilities to support performance confirmation, excavation of exploratory tunnels, and testing and monitoring activities in the drifts. Chapter 3 describes site characterization activities and the resulting affected environment.

Potential health and safety impacts that could occur during preconstruction testing and performance confirmation activities include those common to an industrial work setting, radiological impacts to the public and workers from exposure to radon-222 and its decay products, external radiation exposure of workers in the subsurface environment, and the potential for exposure to naturally occurring hazardous materials generated by excavation activities. Section 4.1.7.2 contains additional information on these potential exposure pathways. No spent nuclear fuel and high-level radioactive waste would be present during preconstruction testing and performance confirmation activities, so radiation exposure of workers from this source would not occur.

Impacts are likely to be very small during preconstruction testing and performance confirmation activities. Incremental health and safety impacts to workers for the performance confirmation period would be less than 2 percent of those estimated for the construction, operation and monitoring, and closure phases, based on comparisons of worker activities and the number of worker-years between site characterization (DIRS 104957-DOE 1994, all) and repository activities (see Appendix F). Potential radiological impacts to members of the public would be less than those estimated for the construction phase (Section 4.1.7.2). The probability of latent cancer fatality in the offsite maximally exposed individual would be about 0.0000002. No latent cancer fatalities (less than 0.004) would be likely in the potentially exposed population.

4.1.7.2 Impacts to Occupational and Public Health and Safety from Initial Construction

This section describes estimates of health and safety impacts to repository workers and members of the public for the 5-year initial construction phase. During this phase, DOE would build the surface facilities, excavate the main drifts, and excavate enough emplacement drifts to support initial emplacement activities. Potential health and safety impacts to workers would occur from industrial hazards, exposure to naturally occurring radionuclides, and exposure to naturally occurring cristobalite and erionite in the rock at the Yucca Mountain site. Potential health impacts to members of the public would be from exposure to airborne releases of naturally occurring radionuclides and hazardous materials.

4.1.7.2.1 *Occupational Health and Safety Impacts*

Industrial Hazards. The analysis estimated health and safety impacts to workers from hazards common to the industrial setting in which they would be working using statistics for similar kinds of operations in the DOE complex and estimates of the total number of full-time equivalent worker years that would be involved in the activity. The statistics that the analysis used are from the DOE Computerized Accident/ Incident Reporting and Recordkeeping System (DIRS 147938-DOE 1999, all). These statistics reflect recent DOE experience for these types of activities. Appendix F, Section F.2.2.2, contains more information on the selection of impact statistics.

Estimates of impacts were based on the number of full-time worker years during the construction phase for the repository operating modes. Table 4-21 lists the estimated impacts to workers from industrial hazards for the repository construction phase. The table lists impacts for three types of industrial safety impacts; total recordable cases of injuries and illnesses that are work-related, total lost workday cases, and fatalities (see the discussion in Appendix F, Section F.2.2).

Table 4-21. Impacts to workers from industrial hazards during initial construction phase.[a,b]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved workers		
Total recordable cases	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers (totals)[c]		
Total recordable cases	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23

a. Source: Appendix F, Table F-12. Numbers are rounded to two significant figures.
b. The analysis assumed that the construction phase would last 44 months for surface facility construction and 60 months for subsurface construction activities.
c. Totals might differ from sums of values due to rounding.

No worker fatalities would be expected during construction for any of the operating modes. For the higher-temperature operating mode, the estimated fatalities are 0.21. The range for the lower-temperature operating mode is 0.21 to 0.23 fatality.

Naturally Occurring Hazardous Materials. Two types of naturally occurring hazardous materials could be encountered by workers at the Yucca Mountain site—cristobalite, a form of crystalline silica (silicon dioxide, SiO_2), and erionite, a naturally occurring zeolite. Both are present in the subsurface rock at Yucca Mountain and have the potential to become airborne during repository excavation and activities involving excavated rock and would be released during tunneling operations. It could also be released with dust from the excavated rock pile. Erionite is a natural zeolite that occurs in the rock layers below the proposed repository level (see Chapter 3, Section 3.1.3). It might also occur in rock layers above the repository level but activities to date have not found it in those layers. Erionite could become a hazard during vertical boring operations if the operations passed through a rock layer containing erionite (which would be unlikely), and during excavation for access to the lower block. Additional information on the potential hazards of these naturally-occurring materials is found in Appendix F, Section F.1.2.

Cristobalite is present in the welded tuff at the repository level and would become airborne in the repository environment during excavation and rock moving activities. The welded tuff has an average cristobalite content of between 18 and 28 percent (DIRS 104523-CRWMS M&O 1999, p. 4-81).

DOE would use engineering controls during subsurface work to control exposures of workers to silica dust. Water would be applied during excavation activities to wet both the rock face and the broken rock to minimize airborne dust levels. Wet or dry dust scrubbers would capture dust that the water sprays did not suppress. The fresh air intake and the exhaust air streams would be separated to prevent increased dust concentrations in the drift atmosphere from recirculation. In addition, the ventilation system would be designed and operated to control ambient air velocities to minimize dust resuspension. DOE would monitor the working environment to ensure that workers were not exposed to dust concentrations higher than the applicable limits for cristobalite. If engineering controls were unable to maintain dust concentrations below the limits, administrative controls such as access restrictions or respiratory protection would be used until the engineering controls could establish acceptable conditions. Similar controls would be applied, if required, for surface workers. DOE expects that exposure of workers to silica dust would be below the applicable limits and potential impacts to subsurface and surface workers would be very small.

DOE does not expect to encounter erionite layers either during vertical boring operations (which would be through rock layers above known erionite layers) or during excavation to provide access to the lower block and offset areas. Access excavation would be planned to avoid any identified layers of erionite (DIRS 104532-McKenzie 1998, all). If erionite was encountered during excavation for access to the lower block or during vertical boring operations, the engineering controls described above for cristobalite would be instituted and, if necessary, administrative controls would be used until acceptable conditions were reestablished.

Radiological Health Impacts. Spent nuclear fuel and high-level radioactive waste would not be present at the repository site during the construction phase and so would not contribute to radiological impacts. Potential radiological health impacts to involved and noninvolved workers in subsurface facilities during the initial construction phase would be from two sources: inhalation of naturally occurring radon-222 and its decay products following emanation of the radon from the surrounding rock, and external radiation dose from naturally occurring radionuclides in the drift walls, principally potassium-40 and radionuclides in the uranium decay series (DIRS 104544-CRWMS M&O 1999, Sections 4 and 5). Radon-222 is a noble gas of the uranium-238 decay series. Because it is a noble gas, radon emanates from the rock into the drifts, where elevated concentrations of radon-222 and its decay products could occur in the repository atmosphere (see Chapter 3, Section 3.1.8.2). Workers in surface facilities and members of the public would also be exposed to naturally occurring radon-222 and decay products as these radionuclides would be released from the subsurface in exhaust ventilation air. Section 4.1.2.2.2 provides more detailed discussion of these airborne release exposures.

Measurements in the Exploratory Studies Facility indicated an underground ambient external dose rate from radionuclides in the drift walls of about 50 millirem per work year of 2,000 hours underground. This is slightly higher than the dose rate from the cosmic and cosmogenic components of natural background radiation on the surface of about 40 millirem per year in the Amargosa Valley region (see Section 3.1.8.2). This analysis considers the underground ambient external radiation dose to be part of the involved worker occupational dose.

Table 4-22 lists estimated potential doses and radiological health impacts for the construction phase to involved workers, noninvolved workers, and the total for all workers. It includes estimated doses and

Table 4-22. Radiation dose and radiological health impacts to workers during the initial construction phase.[a,b,c]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Maximally exposed worker		
Dose, rem		
Involved	1.3	1.3
Noninvolved	0.33	0.33
Probability of latent cancer fatality		
Involved	0.00052	0.00052
Noninvolved	0.00013	0.00013
Worker population		
Collective dose (person-rem)		
Involved	680	680
Noninvolved	37	37
Total[d]	720	720
Number of latent cancer fatalities		
Involved	0.27	0.27
Noninvolved	0.015	0.015
Total[d]	**0.29**	**0.29**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-11.
c. Only subsurface workers have potential for measurable radiation dose (from natural sources) during the initial construction phase.
d. Totals might differ from sums of values due to rounding.

radiological health impacts for the maximally exposed involved worker and for the involved worker population; radiological health impacts for the maximally exposed noninvolved worker and for the noninvolved worker population; and the estimated collective dose and radiological health impacts for the combined population of workers. Estimated doses were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0004 latent cancer fatality per rem (see Appendix F, Section F.1.1.5). Radiological health impacts for maximally exposed individuals are presented as the increase in the probability of a latent cancer fatality resulting from the radiation dose received. Radiological health impacts for exposed populations are presented as the number of latent cancer fatalities estimated to result from the collective radiation dose received.

During the initial construction phase the only source of radiation would be from naturally occurring radionuclides in the subsurface, so radiological health impacts to the surface facility workforce would be much lower than those to the subsurface facility workforce. Values presented in Table 4-22 are those for subsurface workers (see Appendix F, Table F-11).

The estimated increase in the number of latent cancer fatalities for workers would be low (about 0.3); the estimated increase in the likelihood that an individual worker would die from a latent cancer fatality would also be small (about 0.0005).

4.1.7.2.2 *Public Health Impacts*

Naturally Occurring Hazardous Materials. Section 4.1.2.2.1 presents estimated annual average concentrations of cristobalite at the *site boundary* where members of the public could be exposed during the construction phase. The analysis estimated concentrations of about 0.02 microgram per cubic meter for the operating modes, and health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public during the construction phase would come from exposure to airborne releases of naturally occurring radon-222 and its decay products in the subsurface exhaust ventilation air. Estimates of radiation doses for the offsite maximally exposed individual and the potentially exposed population are presented in Section 4.1.2.2.2. The offsite maximally exposed individual is a hypothetical member of the public at a point on the land withdrawal boundary that would receive the highest radiation dose and resultant radiological health impact. This location would be at the southern boundary of the land withdrawal area. The exposed population is that within 80 kilometers (50 miles) of the repository (see Section 3.1.8). Estimated doses to members of the public were converted to estimates of latent cancer fatalities using a dose-to-risk conversion factor of 0.0005 latent cancer fatality per rem for members of the public (see Appendix F, Section F.1.1.5).

Table 4-23 lists the estimated doses and radiological health impacts to members of the public from the 5-year initial construction phase. The radiological health impacts to the public from repository construction would be very small (with 0.02 latent cancer fatality or less estimated for all of the operating modes). The estimated individual risk of contracting a latent cancer fatality for the maximally exposed individual would be 0.000001 or less over the 5-year phase.

Table 4-23. Radiation doses and radiological health impacts to the public during the initial construction phase.[a,b,c]

	Operating mode			
	Entire phase		Maximum annual	
Dose and health impact	Higher-temperature	Lower-temperature	Higher - temperature	Lower-temperature
Maximally exposed individual[d]				
Dose (millirem)	1.7	1.7 - 2.0	0.43	0.43 - 0.53
Latent cancer fatality probability	8.5×10^{-7}	$0.85 - 1.0 \times 10^{-6}$	2.1×10^{-7}	$2.1 - 2.6 \times 10^{-7}$
Exposed 80-km population[e]				
Collective dose (person-rem)	33	33 - 40	8.4	8.4 - 10
Number of latent cancer fatality	0.017	0.017 - 0.020	0.0042	0.0042 - 0.0052

a. Numbers are rounded to two significant figures.
b. Source: Table 4-2.
c. All of the dose and impact are from naturally occurring radon-222 and decay products.
d. Located at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

4.1.7.3 Occupational and Public Health and Safety Impacts from Operation and Monitoring

This section describes possible health and safety impacts to workers and members of the public for the operation and monitoring phase. This phase has two main components: the operations period (including continuing subsurface development) and the monitoring period. The overall phase length would range from 100 years for the higher-temperature operating mode up to 324 years for the lower-temperature operating mode. Impacts of the operations period and the monitoring period are described below.

4.1.7.3.1 *Operations Period – Handling, Emplacement, and Continuing Development*

This period would consist of a 24-year period for operations, including the receipt, handling, packaging, possible aging, and emplacement of spent nuclear fuel and high-level radioactive waste. There would be a concurrent (except for the last two years) 22-year period for continued construction (development) of underground repository features, including access drifts, emplacement drifts, shafts, and so on. Where aging of commercial spent nuclear fuel could occur under the lower temperature operating mode an additional 26 years of emplacement and handling would be needed, for a total operations period length of 50 years.

4.1.7.3.1.1 Occupational Impacts

Industrial Hazards. Table 4-24 summarizes health and safety impacts from common industrial hazards for the operations period. Impacts were estimated separately for surface operations, subsurface emplacement operations, and subsurface drift development operations, then were summed to develop these results.

Table 4-24. Impacts to workers from industrial hazards during the operations period.[a]

	Operating mode	
Worker group and impact category	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	1,200	1,200 - 1,700
Lost work day cases	590	620 - 840
Fatalities	0.90	0.91 - 1.4
Noninvolved workers		
Total recordable cases	300	310 - 470
Lost workday cases	150	150 - 230
Fatalities	0.31	0.31 - 0.45
All workers (totals)[b]		
Total recordable cases	1,500	1,500 - 2,200
Lost workday cases	740	770 - 1,100
Fatalities	1.2	1.2 - 1.9

a. Values taken from Appendix F, Table F-22.
b. Totals might differ from sums of values due to rounding.

About 1.2 fatalities were estimated for the higher-temperature operating mode, with a range of 1.2 to 1.9 fatalities estimated for the lower-temperature operating mode. The highest estimates would be where aging would be used (longer operations period, more worker-years) with maximum spacing of the waste packages, which results in the largest repository and thus more excavation.

Naturally Occurring Hazardous Material. As discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures to control and minimize impacts to workers from releases of cristobalite and erionite during the operations period. Controls would be necessary mainly for continuing development activities underground but also for activities associated with the excavated rock pile. As for the construction phase, impacts would be expected to be very small.

Radiological Health Impacts. Occupational radiological health impacts during the operations period would be a combination of impacts to surface workers during handling operations, and impacts to subsurface workers during development and emplacement operations. These impacts are presented in Table 4-25.

The estimated radiological health impacts to the worker population for the 24 or 50-year operations period would range from 3.1 to 4.8 latent cancer fatalities. Estimated radiological health impacts to the maximally exposed individual would range from 15 to 30 rem, with a corresponding probability of latent cancer fatality ranging from 0.0060 to 0.012. The principal contributors to radiological health impacts would be surface facility operations, which would involve the receipt, handling, and packaging of spent nuclear fuel and high-level radioactive waste for emplacement and subsurface monitoring activities.

Table 4-25. Radiation dose and radiological health impacts to workers during the operations period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker		
Dose, rem		
Involved	15	15 - 30
Noninvolved	1.5	1.5 - 1.8
Probability of latent cancer fatality		
Involved	0.0060	0.0060 - 0.012
Noninvolved	0.00060	0.00060 - 0.00072
Worker population		
Collective dose (person-rem)		
Involved	7,500	7,600 - 12,000
Noninvolved	150	160 - 170
Total[c]	**7,700**	**7,800 - 12,000**
Number of latent cancer fatalities		
Involved	3.0	3.0 - 4.8
Noninvolved	0.060	0.064 - 0.068
Total[c]	**3.1**	**3.1 - 4.8**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-23.
c. Totals might differ from sums of values due to rounding.

DOE would consider the inspection, testing, or retrieval of a waste package that had already been emplaced to be an off-normal condition of routine operations that it has already considered (see Chapter 2, Section 2.1.2.2.3). Any such operation would be carried out under the repository radiation protection program, and worker dose limits would apply. Therefore, any radiation dose from such an operation would already be included in the estimated doses to the maximally exposed workers and worker populations listed in Table 4-25.

4.1.7.3.1.2 Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of about 0.009 to 0.017 microgram per cubic meter for the operating modes. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from operations period activities could result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air, and from exposure to radioactive noble gas fission products, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations. Krypton-85 and other noble gas fission products would be very small contributors to dose and potential radiological impacts, less than 0.01 percent of the dose from radon-222 and its decay products (see Section 4.1.2.3.2).

Section 4.1.2.3.2 presents estimates of dose to the public for the handling, emplacement, and continuing development (operations) period. Table 4-26 presents these doses and the potential radiological health impacts to the public for that period. Potential radiological health impacts would be very small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.000022 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.12 to 0.42.

Table 4-26. Radiation doses and radiological health impacts to the public during the operations period.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Dose and health impact	Entire period		Maximum annual	
Maximally exposed individual[e]				
Dose (millirem)	12	17 - 43	0.73	1.0 - 1.3
Latent cancer fatality probability	6.0×10^{-6}	$0.83 - 2.2 \times 10^{-5}$	3.7×10^{-7}	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population[f]				
Collective dose (person-rem)	230	320 - 830	14	20 - 26
Number of latent cancer fatality	0.12	0.16 - 0.42	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.
b. Source: Table 4-4.
c. Greater than 99.9 percent of the dose would be from naturally occurring radon-222 and decay products.
d. Fuel handling activities during the operation and monitoring phase would last 24 years. Emplacement activities would last 24 years with no aging, and 50 years with aging. Continued subsurface development activities would last 22 years.
e. Individual located at the southern boundary of the land withdrawal area for all of the operations period (24 or 50 years).
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Section 3.1.8).

4.1.7.3.2 *Monitoring Period*

This period would last 76 years under the higher-temperature operating mode and up to 300 years under lower-temperature operating modes. The first 3 years of this period would include decontamination of surface fuel handling facilities in preparation for the long periods of monitoring and maintenance to follow, and ultimately for closure. Only monitoring and maintenance activities would take place during the remainder of the period, including periodic replacement of the solar facility components. Most of the potential operating modes would include active ventilation during this period, but 250 years of natural ventilation could be used, during which there would be lower ventilation flow rates (see Section 2.1.1.2.2).

4.1.7.3.2.1 Occupational Impacts

Industrial Hazards. Table 4-27 lists health and safety impacts from common industrial hazards for the monitoring period, including decontamination activities. Impacts were estimated separately for the surface facility decontamination operations, surface operations to support subsurface monitoring, and subsurface monitoring itself.

About 0.4 fatality would be expected to occur for the higher-temperature operating mode. The range of fatalities predicted for the lower-temperature operating mode is 0.44 to 1.1 fatalities with the largest value for long-term ventilation with aging of the spent nuclear fuel.

Naturally Occurring Hazardous Material. During monitoring and maintenance activities there would be little opportunity for large quantities of dust to be generated for extended periods of time. If necessary, and as discussed in Section 4.1.7.2.1 for the construction phase, DOE would use engineering controls and, if necessary, administrative worker protection measures such as respiratory protection to control and minimize impacts to workers from releases of cristobalite and erionite during monitoring activities.

Radiological Health Impacts. Occupational radiological health impacts during the monitoring period would be a combination of impacts to surface workers during facility decontamination and subsurface workers during monitoring and maintenance activities. These impacts are presented in Table 4-28.

Table 4-27. Impacts to workers from industrial hazards during the monitoring period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Involved workers		
Total recordable cases	320	400 - 1,000
Lost work day cases	130	160 - 410
Fatalities	0.31	0.38 - 1.0
Noninvolved workers		
Total recordable cases	55	65 - 150
Lost workday cases	27	32 - 73
Fatalities	0.049	0.057 - 0.13
All workers (totals)[c]		
Total recordable cases	380	470 - 1,200
Lost workday cases	160	190 - 480
Fatalities	0.36	0.44 - 1.1

a. Values are rounded to two significant figures.
b. Source: Appendix F, Table F-31.
c. Totals might differ from sums of values due to rounding.

Table 4-28. Radiation dose and radiological health impacts to workers during the monitoring period.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[c]		
Dose, rem		
Involved	18	18
Noninvolved	1.8	1.8
Probability of latent cancer fatality		
Involved	0.0072	0.0072
Noninvolved	0.00072	0.00072
Worker population		
Collective dose (person-rem)		
Involved	1,100	1,500 - 4,300
Noninvolved	36	46 - 140
Total[d]	**1,100**	**1,500 - 4,400**
Number of latent cancer fatalities		
Involved	0.44	0.60 - 1.7
Noninvolved	0.014	0.018 - 0.056
Total[d]	**0.44**	**0.60 - 1.8**

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-32.
c. Maximally exposed worker is a subsurface involved worker who works in the subsurface environment for 50 years.
d. Totals might differ from sums of values due to rounding.

The estimated radiological health impacts to the worker population for the 76- to 300-year monitoring period would range from 0.44 to 1.8 latent cancer fatalities. The relatively wide range in impacts is due mainly to the differences in the length of the monitoring periods. Estimated radiological health impacts to the maximally exposed individual would be 18 rem for the range of operating modes, with a corresponding probability of latent cancer fatality of 0.0072. Estimated doses and radiological health impacts to the maximally exposed worker are based on a 50-year working lifetime. The principal contributor to radiological health impacts would be from subsurface facility monitoring and maintenance activities.

4.1.7.3.2.2 Public Health Impacts

Naturally Occurring Hazardous Materials. Section 4.1.2.3.1 presents estimated annual average concentrations of cristobalite at the land withdrawal boundary where members of the public could be exposed during the operation and monitoring phase. The analysis estimated annual average concentrations of 0.009 to 0.017 microgram per cubic meter; however, these concentrations are likely more representative of operations period activities while those during the monitoring period would be even lower. Health impacts to the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower than for cristobalite at locations of public exposure. Impacts would be very small.

Radiological Health Impacts. Potential radiological health impacts to the public from monitoring period activities would result from exposure to naturally occurring radon-222 and its decay products released in subsurface exhaust ventilation air. No releases of radioactive material or radiation dose to the public are anticipated for decontamination activities (DIRS 152010-CRWMS M&O 2000, pp. 55-56).

Section 4.1.2.3.2 presents estimates of dose to the public for the monitoring period. Table 4-29 lists these doses and potential radiological health impacts to the public for that period. Potential radiological health impacts would be low. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.000031 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.75 to 1.7. Because of the length of the monitoring period compared to other project periods, most of the estimated radiological impacts to the public would occur during this period.

Table 4-29. Radiation doses and radiological health impacts to the public during the monitoring period.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Dose and health impact	Entire period		Maximum annual	
Maximally exposed individual[e]				
Dose (millirem)	29	30 - 62	0.41	0.59 - 0.89
Latent cancer fatality probability	1.5×10^{-5}	$1.5 - 3.1 \times 10^{-5}$	2.1×10^{-7}	$3 - 4.4 \times 10^{-7}$
Exposed 80-kilometer population[f]				
Collective dose (person-rem)	600	1,500 - 3,500	8	11 - 17
Number of latent cancer fatalities	0.31	0.75 - 1.7	0.004	0.0057 - 0.0085

a. Numbers are rounded to two significant figures.
b. Source: Table 4-5.
c. All dose would be from naturally occurring radon-222 and decay products.
d. Monitoring and maintenance period would last from 76 to 300 years.
e. Individual located at the southern boundary of the land withdrawal area for 10 years.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

4.1.7.4 Impacts to Occupational and Public Health and Safety from Closure

This section contains estimates of health and safety impacts to workers and to members of the public for the closure phase. The length of this phase depends on the operating mode. The higher-temperature operating mode closure phase would last 10 years, while closure for the lower-temperature operating mode would range from 11 to 17 years in length.

4.1.8.2 Nonradiological Accidents

A potential release of hazardous or toxic materials during postulated operational accidents involving spent nuclear fuel or high-level radioactive waste at the repository would be very unlikely. Because of the large quantities of radioactive material, radiological considerations would outweigh nonradiological concerns. The repository would not accept hazardous waste as defined by the Resource Conservation and Recovery Act. Some potentially hazardous metals such as arsenic or mercury could be present in the high-level radioactive waste. However, they would be in a vitrified glass matrix that would make the exposure of workers or members of the public from operational accidents highly unlikely. Appendix A contains more information on the inventory of potentially hazardous materials.

Some potentially nonradioactive hazardous or toxic substances would be present in limited quantities at the repository as part of operational requirements. Such substances would include liquid chemicals such as cleaning solvents, sodium hydroxide, sulfuric acid, and various solid chemicals (see Section 4.1.3.2). These substances are in common use at other DOE sites. Section 4.1.7 describes potential impacts to workers from normal industrial hazards in the workplace (which includes industrial accidents). The statistics used in the analysis were derived from DOE accident experience at other sites. Impacts to members of the public would be unlikely because the chemicals would be mostly liquid and solid so that any release would be confined locally. (For example, chlorine at the site used for water treatment would be in powder form, so a gaseous release of chlorine would not be possible. Propane gas would not be stored at the site.)

Section 4.1.12.2 describes the quantities of solid hazardous waste generated during repository operations. The construction and closure phases would not generate liquid hazardous waste. The generation, storage, and shipment off the site of solid and liquid hazardous waste generated during operations would represent minimal incremental risk from accidents. Impacts to workers from industrial accidents in the workplace are part of the statistics presented in Appendix F, Section F.2.

4.1.8.3 Sabotage

In the aftermath of the tragic events of September 11, DOE is continuing to assess measures that it could take to minimize the risk or potential consequences of radiological sabotage or terrorist attacks against our Nation's proposed monitored geologic repository.

Over the long term (after closure), deep geologic disposal of spent nuclear fuel and high-level radioactive waste would provide optimal security by emplacing the material in a geologic formation that would provide protection from inadvertent and advertent human intrusion, including potential terrorist activities. The use of robust metal waste packages to contain the spent nuclear fuel and high-level radioactive waste more than 200 meters (660 feet) below the surface would offer significant impediments to any attempt to retrieve or otherwise disturb the emplaced materials.

In the short term (prior to closure), the proposed repository at Yucca Mountain would offer certain unique features from a safeguards perspective: a remote location, restricted access afforded by Federal land ownership and proximity to the Nevada Test Site, restricted airspace above the site, and access to a highly effective rapid-response security force.

Current Nuclear Regulatory Commission regulations (10 CFR 63.21 and 10 CFR 73.51) specify a repository performance objective that provides "high assurance that activities involving spent nuclear fuel and high-level waste do not constitute an unreasonable risk to public health and safety." The regulations require that spent nuclear fuel and high-level radioactive waste be stored in a protected area such that:

- Access to the material requires passage through or penetration of two physical barriers. The outer barrier must have isolation zones on each side to facilitate observation and threat assessment, be continually monitored, and be protected by an active alarm system.
- Adequate illumination must be provided for observation and threat assessment.
- The area must be monitored by random patrol.
- Access must be controlled by a lock system, and personnel identification must be used to limit access to authorized persons.

A trained, equipped, and qualified security force is required to conduct surveillance, assessment, access control, and communications to ensure adequate response to any security threat. Liaison with a response force is required to permit timely response to unauthorized entry or activities. In addition, the Nuclear Regulatory Commission requires (10 CFR Part 63, by reference to 10 CFR Part 72) that comprehensive receipt, periodic inventory, and disposal records be kept for spent nuclear fuel and high-level radioactive waste in storage. A duplicate set of these records must be kept at a separate location.

DOE believes that the safeguards applied to the proposed repository should involve a dynamic process of enhancement to meet threats, which could change over time. Repository planning activities would continue to identify safeguards and security measures that would further protect fixed facilities from terrorist attack and other forms of sabotage. Additional measures that DOE could adopt include:

- Facilities with thicker reinforced walls and roofs designed to mitigate the potential consequences of the impact of airborne objects
- Underground or surface bermed structures to lessen the severity of damage in cases of aircraft crashes
- Additional doors, airlocks, and other features to delay unauthorized intrusion
- Additional site perimeter barriers to provide enhanced physical protection of site facilities
- Active denial systems to disable any adversaries, thereby preventing access to the facility

Although it is not possible to predict if sabotage events would occur, and the nature of such events if they did occur, DOE examined various accident scenarios that approximate the types of consequences that could occur. These accidents and their consequences are discussed in Section 4.1.8.1.

4.1.9 NOISE IMPACTS

This section describes possible noise impacts to the public (nuisance noise) and workers (occupational noise) from performance confirmation, construction, operation and monitoring, and closure activities. Repository areas that could generate elevated noise levels include the North Portal, South Portal, Emplacement Shaft, and Development Shaft Operations Areas. The following discussion identifies potential impacts that primarily would affect workers during routine operations. Overall, however, the potential for noise impacts to the public would be very small due to the distances of residences from these areas. Section 4.1.4.2 discusses noise impacts on wildlife.

4.1.9.1 Noise Impacts from Performance Confirmation

As part of site characterization, DOE has evaluated existing noise conditions in the Yucca Mountain region. The noise associated with site characterization activities, which has included that from construction, equipment, drilling equipment, and occasional blasting, has not resulted in noticeable impacts. Because performance confirmation activities would be similar to those for site characterization, no impacts would be expected.

4.1.9.2 Noise Impacts from Construction, Operation and Monitoring, and Closure

Sources of noise in the analyzed land withdrawal area during the construction phase would include activities at the North Portal and Ventilation Shaft Operations Areas and South Portal Development Area involving heavy equipment (bulldozers, graders, loaders, pavers, etc.), cranes, ventilation fans, and diesel generators. Sources of noise during the operation and monitoring phase would include transformer noise, compressors, ventilation fans, air conditioners, and a concrete batch plant. Ventilation fans would have silencers that would keep noise levels below 85 dBA (see Chapter 3, Section 3.1.9 for an explanation of noise measurements) at a distance of 3 meters (10 feet) (DIRS 100235-CRWMS M&O 1997, p. 107). The Occupational Safety and Health Administration has identified that the maximum permissible continuous noise level that workers may be exposed to without controls is 90 dBA [29 CFR 1910.95(b)(2)].

The distance from the North Portal Operations Area to the nearest point on the boundary of the analyzed land withdrawal area analyzed would be about 11 kilometers (7 miles) due west. The distance from the South Portal Development Area to the nearest point on the land withdrawal area boundary would also be about 11 kilometers due west. The point on the boundary closest to a Ventilation Shaft Operations Area would be about 7 kilometers (4 miles) (DIRS 104852-YMP 1997, all).

To establish the propagation distance of repository-generated noise for analysis purposes, DOE used an estimated maximum sound level [132 decibels, A-weighted (dBA) for heavy construction equipment, although heavy trucks generate sound levels of between 70 and 80 dBA at 15 meters (50 feet)]. An analysis determined the distance at which that noise would be at the lower limit of human hearing (20 dBA). The calculated distance was 6 kilometers (3.7 miles). Thus, noise impacts would be unlikely at the land withdrawal area boundary.

Because the distance between repository noise sources and a hypothetical individual at the land area withdrawal boundary would be large enough to reduce the noise to background levels and because there would be no residential or community receptors at the withdrawal area boundary [the nearest housing is in Amargosa Valley about 22 kilometers (14 miles) from the repository site], DOE expects no noise impacts to the public from repository construction and operations.

Workers at the repository site could be exposed to elevated levels of noise. Small impacts such as speech interference between workers and annoyance to workers would occur. However, worker exposures during all *repository phases* would be controlled such that impacts (such as loss of hearing) would be unlikely. Engineering controls would be the primary method of noise control. Hearing protection would be required, as needed, as a supplement to engineering controls.

Noise impacts associated with closure would be similar to those associated with construction and operations. Therefore, DOE expects no noise impacts to the public and workers.

estimates, material use estimates, and number of workers. The evaluation assessed these quantities against current public and private capacity to treat and dispose of wastes.

4.1.12.1 Waste and Materials Impacts from Preconstruction Testing and Performance Confirmation

DOE expects preconstruction testing and performance confirmation activities to generate waste similar to and in about the same quantities as that generated during characterization activities with the exception that low-level radioactive waste would be generated in minimal quantities (DIRS 104508-CRWMS M&O 1999, p. 17). Based on 1997 waste generation reports, preconstruction testing and performance confirmation activities should produce about 3,200 cubic meters (110,000 cubic feet) of nonhazardous construction debris and sanitary and industrial solid waste (DIRS 104952-Sygitowicz 1998, pp. 2 and 4) and about 170 kilograms (380 pounds) (volume measurements were not available) of hazardous waste (DIRS 104882-Harris 1998, pp. 3 through 6) that would require disposal. In addition, other waste would be recycled rather than disposed. Wastewater would be generated from runoff, subsurface activities, restrooms, and change rooms.

WASTE TYPES

Construction/demolition debris: Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include such materials as soil, rock, masonry materials, and lumber.

Industrial wastewater: Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression, rinsewater from concrete production and transport, and process water from building heating, ventilation, and air conditioning systems.

Low-level radioactive waste: Radioactive waste that is not classified as high-level radioactive waste, transuranic waste, byproduct material containing uranium or thorium from processed ore, or naturally occurring radioactive material. The repository low-level radioactive waste would include such wastes as personal protective clothing, air filters, solids from the liquid low-level radioactive waste treatment process, radiological control and survey waste, and possibly used canisters (dual-purpose).

Sanitary sewage: Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

Sanitary and industrial solid waste: Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as *household waste*.

Hazardous waste: Waste designated as hazardous by the Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents.

DOE would use current (as described in Chapter 3, Section 3.1.12) or similar methods to handle the waste streams generated by its preconstruction testing and performance confirmation activities. It would also use offsite landfills to dispose of solid waste and construction debris; accumulate and consolidate hazardous waste and transport it off the site for treatment and disposal; treat and reuse wastewater; and treat and dispose of sanitary sewage. Based on site characterization experience, these activities would result in only small impacts to the regional waste disposal capacity.

4.1.12.2 Waste and Materials Impacts from Construction, Operation and Monitoring, and Closure

The construction phase would generate nonhazardous, nonradioactive wastes and some hazardous waste from the use of such materials as resins, paints, and solvents. Nonhazardous, nonradioactive wastes would include sanitary and industrial solid wastes, construction debris, industrial wastewater, and sanitary sewage. Table 4-40 lists the estimated quantities of waste that the construction phase would generate. These estimates are based on construction experience, water use estimates, and Yucca Mountain Site Characterization Project experience with wastewater generation from dust suppression.

Table 4-40. Waste quantities generated during the construction phase.

	Operating mode	
Waste type	Higher-temperature	Lower-temperature
Construction debris (cubic meters)[a]	5,000	5,000 - 9,300
Hazardous (cubic meters)	1,200	1,200 - 2,300
Sanitary and industrial solid (cubic meters)	11,000	12,000
Sanitary sewage (million liters)[b]	180	180
Industrial wastewater (million liters)	46	55 - 59

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. However, as part of the Proposed Action, DOE would construct a State-permitted landfill on the Yucca Mountain site to dispose of nonrecyclable construction debris and sanitary and industrial solid waste. Section 2.1.2.1.4.3 describes the landfill. If the repository generates construction and demolition debris and sanitary and industrial waste beyond the capacity of this landfill, the excess nonhazardous waste would be disposed of at Nevada Test Site landfills. As listed in Table 4-40, DOE estimates a maximum of 9,300 cubic meters (330,000 cubic feet) of construction debris. If the Department chose not to build a landfill at the repository site, it could ship construction debris to the Test Site's Area 9 U10C Landfill, which has a disposal capacity of 990,000 cubic meters (35 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37). The disposal of construction debris generated during the construction phase would consume less than 1 percent of the disposal capacity in this landfill. DOE could also ship repository-generated sanitary and industrial solid waste to the Test Site for disposal in the Area 23 landfill, which has a capacity of 450,000 cubic meters (16 million cubic feet) (DIRS 101811-DOE 1996, p. 4-37). The disposal of the maximum of 12,000 cubic meters (420,000 cubic feet) of sanitary and industrial solid waste generated during the construction phase at the Area 23 landfill would use less than 3 percent of the disposal capacity.

DOE would package hazardous waste and ship it off the site for treatment and disposal. The Department could continue to dispose of such waste in conjunction with the Nevada Test Site, which has contracts with commercial facilities, or could contract separately with the same or another commercial facility. No more than 2,300 cubic meters (81,000 cubic feet) of hazardous waste (see Table 4-40), weighing 2,300 metric tons (2,500 tons), would be generated during the construction phase. By comparison, 44,000 metric tons (48,000 tons) of hazardous waste was managed in Nevada in 1999 (DIRS 156935-EPA 2001, pp. ES-7). Regional capacity for treatment and disposal of hazardous waste is much greater than the quantity that would be generated at Yucca Mountain. For example, the hazardous waste incineration capacity in western states through 2013 has been estimated at seven times the demand for this service (DIRS 103245-EPA 1996, pp. 32, 33, 35, 46, 47, and 50). The landfill capacity for hazardous waste disposal would be about 50 times the demand. Therefore, the impact on regional hazardous waste capacity from repository-generated hazardous waste during the construction phase would be very small.

DOE would treat and dispose of sanitary sewage and industrial wastewater at onsite facilities. Sanitary sewage from the North Portal Operations Area would go to an existing septic system. The Department would install another septic system to dispose of sanitary sewage from the South Portal Development Area. The industrial wastewater from surface facilities would flow to an evaporation pond at the North Portal Operations Area and wastewater from the subsurface would flow to an evaporation pond at the South Portal Development Area. Sludge would accumulate in the North Portal Operations Area evaporation pond so slowly that DOE would not need to remove it before the closure of the pond (DIRS 102599-CRWMS M&O 1998, pp. 65 to 67). The accumulated sludge at the South Portal Development Area evaporation pond, which would consist of mined rock, portland cement, and fine aggregate, would be removed as needed and added to the excavated rock pile (DIRS 104910-Koppenaal 1998, p. 3). In addition, under the lower-temperature operating mode with surface aging, DOE would install a small evaporation pond for rinsewater from the concrete batch plant as needed.

Activities during the operation and monitoring phase would generate radioactive and nonradioactive wastes and wastewaters and some hazardous waste. DOE does not expect to generate mixed waste. However, repository facilities would have the capability to package and temporarily store mixed waste that operations could generate under unusual circumstances. In addition, the medical clinic would generate a small amount of medical waste that DOE would dispose of in accordance with applicable Federal and State of Nevada requirements. Table 4-41 lists the estimated total waste quantities for repository activities associated with the operation and monitoring phase. These estimates do not include used solar panels because DOE anticipates that recycling options would be available by the time the first solar panels would require replacement, about 2030. Solar panel replacement once every 20 years (DIRS 153882-Griffith 2001, p. 8) would generate about 350 metric tons (390 tons) of material for recycling. Replacement would occur 4 to 16 times, depending on the operating mode.

Table 4-41. Waste quantities generated during the operation and monitoring phase.

	Operating mode	
Waste type	Higher-temperature	Lower-temperature
Low-level radioactive (cubic meters)[a]	68,000	68,000 - 91,000
Hazardous (cubic meters)	6,100	5,600 - 6,300
Sanitary and industrial solid (cubic meters)	81,000	91,000 - 150,000
Sanitary sewage(million liters)[b]	1,800	2,100 - 3,200
Industrial wastewater (million liters)	900	850 - 980

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

Major waste-generating activities during the operation and monitoring phase would include the receipt and packaging of spent nuclear fuel and high-level radioactive waste and continued development of subsurface emplacement areas. Differences in nonradioactive waste quantities from subsurface activities would be due to the different workforce sizes, main drift lengths, and emplacement spacing. Operating mode differences would affect the volumes of hazardous and low-level radioactive wastes generated at the surface facilities as a result of differences in handling the spent nuclear fuel and high-level radioactive waste, and of phase length if waste was aged on the surface. In addition, waste would be generated in personnel areas such as change rooms, restrooms, and offices. If dual-purpose canisters were used and not recycled, the low-level radioactive waste from the canisters would amount to an estimated 29,000 cubic meters (1,000,000 cubic feet) with an estimated weight of 150,000 metric tons (170,000 tons).

However, the total amount of low-level radioactive waste expected using dual-purpose canisters even with the canisters being disposed of rather than recycled would not exceed the amount listed in Table 4-41, which represents the amount expected from the receipt of uncanistered spent nuclear fuel. DOE could decide to recycle the canisters if doing so would be more protective of the environment and more cost effective than direct disposal. Recycling would require melting and recasting of the canister metal to enable other uses.

Monitoring and maintenance activities after the completion of emplacement would also generate wastes, but in much smaller quantities. The first few years after the completion of emplacement would generate greater quantities of waste due to the decontamination and decommissioning of surface nuclear facilities. DOE estimates as much as 700 cubic meters (25,000 cubic feet) of low-level radioactive waste and as much as 280 cubic meters (9,900 cubic feet) of hazardous waste from this activity.

Monitoring and maintenance activities for 76 years under the higher-temperature operating mode would generate a maximum of about 20,000 cubic meters (710,000 cubic feet) of sanitary and industrial solid waste and about 430 million liters (110 million gallons) of sanitary sewage. Monitoring and maintenance activities for 300 years under the lower-temperature operating mode would generate a maximum of about 84,000 cubic meters (about 2.9 million cubic feet) of sanitary and industrial solid waste and about 1.8 billion liters (480 million gallons) of sanitary sewage. Monitoring for periods bounded by these timeframes would generate the same wastes in proportional quantities.

DOE would treat low-level radioactive waste in the Waste Treatment Building (see Section 2.1.2.1.1.3). After treatment, DOE would need to dispose of an estimated maximum 91,000 cubic meters (3.2 million cubic feet) of low-level radioactive waste generated during emplacement activities and the decontamination of surface nuclear facilities. This waste would be disposed of at the Nevada Test Site. The Test Site accepts low-level radioactive waste for disposal from other DOE sites. It has an estimated total disposal capacity of 3.7 million cubic meters (130 million cubic feet) (DIRS 155856-DOE 2000, Table 4-1) (see Section 3.1.12). The reserve capacity (the total capacity reduced by the volume projected to be needed for disposal of other DOE low-level radioactive waste) is 2.6 million cubic meters (92 million cubic feet) (DIRS 155856-DOE 2000, Table 4-1). The impact to the reserve capacity at the Nevada Test Site from the disposal of repository low-level radioactive waste would be 3.5 percent.

During the operation and monitoring phase DOE would dispose of sanitary sewage and industrial wastewater in the onsite wastewater systems and sanitary and industrial solid waste in the onsite landfill or at the Nevada Test Site. The sanitary sewage disposal system would be able to handle the estimated daily sewage flows, and the industrial wastewater facilities would be able to handle the estimated annual wastewater flows. DOE would use the onsite landfill to dispose of sanitary and industrial solid waste, or it could use the existing Nevada Test Site landfill in Area 23 to dispose of such waste. The Area 23 landfill has an estimated 100-year capacity for the disposal of waste generated at the Test Site (DIRS 101803-DOE 1995, p. 9); the addition of repository-generated waste during the operation and monitoring phase would necessitate its expansion.

During the operation and monitoring phase repository-generated hazardous waste would be shipped off the site for treatment and disposal in a permitted facility. DOE would need to dispose of an estimated maximum of 6,300 cubic meters (220,000 cubic feet) of hazardous waste generated by emplacement activities and the decontamination of surface facilities. The estimated maximum annual rate of hazardous waste treatment or disposal would be about 280 cubic meters (9,900 cubic feet), weighing 270 metric tons (300 tons). This peak annual volume is 1 percent of the volume of hazardous waste that was managed in Nevada in 1999. At present, a number of commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. Regional capacity for treatment and disposal of hazardous waste is much greater than the quantity that would be generated at Yucca Mountain. For example, the estimated hazardous waste incineration capacity in western states through 2013 is seven times the demand for this service (DIRS 103245-EPA 1996, pp. 32, 33, 35, 46, 47, and 50). The landfill capacity for hazardous waste disposal would be about 50 times the demand. Therefore, the impact on regional hazardous waste capacity from repository-generated hazardous waste during the operation and monitoring phase would be very small.

If unusual activities generated mixed waste, DOE would package such waste for offsite treatment and disposal. The estimated maximum annual quantity would be about 1.3 cubic meter (46 cubic feet), which would have a very small impact on the receiving facility. At present, there is commercial capacity (for example, at Envirocare of Utah, with which the Department has a contract for the treatment and disposal of mixed waste). DOE is also pursuing a permit for a mixed waste disposal facility at the Nevada Test Site that would accept mixed waste from other DOE sites for disposal. This facility has a planned capacity of 20,000 cubic meters (710,000 cubic feet) (DIRS 155856-DOE 2000, p. 2-32).

Closure activities, such as the final decontamination and demolition of the repository structures and the restoration of the site, would generate waste and recyclable materials. Table 4-42 lists estimated waste quantities for the closure phase. The ranges of quantities result from more waste generated from more years to complete closure and differences in surface facilities.

Table 4-42. Waste quantities generated during the closure phase.

	Operating mode	
Waste type	Higher temperature	Lower temperature
Demolition debris (cubic meters)[a]	220,000	220,000 - 440,000
Hazardous (cubic meters)	1,200	1,100 - 1,200
Sanitary and industrial (cubic meters)	9,500	9,300 - 12,000
Sanitary sewage (million liters)[b]	160	170 - 250
Industrial wastewater (million liters)	70	77 - 120
Low-level radioactive (cubic meters, after treatment)	3,500	3,200 - 4,600

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

DOE would dispose of demolition debris and sanitary and industrial solid waste in the onsite landfill (or at the Nevada Test Site), and sanitary sewage and industrial wastewater in the onsite septic systems and industrial wastewater system. After disposing of the waste and wastewater, DOE would close the landfill and evaporation ponds in a manner that met applicable requirements.

The Nevada Test Site landfills would have to continue operating past their estimated lives and to expand as needed. The Area 9 U10C Landfill, which accepts demolition debris, has an estimated 70-year operational life; the Area 23 landfill, which is used for sanitary and industrial solid waste disposal, has a 100-year estimated life (DIRS 101803-DOE 1995, pp. 8 and 9).

DOE would continue to dispose of hazardous and low-level radioactive wastes off the site. The Department would ship hazardous waste to an offsite vendor with the appropriate permits and available treatment and disposal capacity. The available capacity for hazardous waste treatment and disposal in the western states would far exceed the demand for many years to come (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Therefore, hazardous waste generated during closure activities would be likely to have a very small impact on the capacity for treatment and disposal at commercial facilities. DOE would ship low-level radioactive waste to a Nevada Test Site disposal facility. The disposal of low-level radioactive waste generated during repository closure at the Nevada Test Site would affect the reserve disposal capacity about two-tenths of 1 percent.

Overall Impacts to Waste Management

The overall impact of managing the Yucca Mountain repository waste streams would differ little among the operating modes, in part because DOE would build onsite facilities to accommodate construction and demolition debris, sanitary and industrial solid wastes, sanitary sewage, and industrial wastewater. Although such activities are not currently planned, the use of existing Nevada Test Site landfills for the disposal of construction and demolition debris and sanitary and industrial solid waste would require the continuation of the operation of these facilities past their estimated lifetimes of 70 and 100 years (DIRS 101803-DOE 1995, pp. 8 and 9). Such use would probably require the expansion of landfill capacities. Use of the Nevada Test Site U10C landfill for construction and demolition debris would require at least 61 percent of the reserve capacity, and could exceed the disposal capacity by 20 percent if 440,000 cubic meters (16 million cubic feet) was to be disposed at the landfill. Use of the Nevada Test Site Area 23 landfill for sanitary and industrial solid waste disposal would use 23 to 37 percent of the disposal capacity. Further review under the National Environmental Policy Act would be completed, as required, to expand capacity of the landfills at the Nevada Test Site.

Repository-generated low-level radioactive and hazardous waste would have little impact at disposal facilities, which could readily accommodate this waste. DOE would use less than 4 percent of the reserve capacity for low-level radioactive waste disposal at the Nevada Test Site. A very small fraction of the existing offsite capacity would be used for repository-generated hazardous waste. The peak annual volume of hazardous waste would be 1 percent of the volume of hazardous waste managed in Nevada in 1999, when the State ranked fortieth in the Nation for the amount of hazardous waste managed (DIRS 156935-EPA 2001, p. ES-7). Nationally, hazardous waste treatment and disposal facilities received 6.0 million metric tons (6.6 million tons) of hazardous waste in 1999 (DIRS 156935-EPA 2001, p. ES-10). As noted above, the projected available capacity through 2013 for treatment and disposal of hazardous waste greatly exceeds demand. The impact to hazardous waste treatment and disposal capacity from repository-generated hazardous waste would be very small.

Table 4-43 lists waste quantities generated for the higher-temperature operating mode and the range of estimated waste quantities for the lower-temperature operating mode for all phases. If not recycled, dual-purpose canisters would add an estimated 29,000 cubic meters (1,000,000 cubic feet) of low-level waste.

Table 4-43. Total waste quantities generated for all phases.[a]

Waste type	Operating mode	
	Higher-temperature	Lower-temperature[b]
Construction and demolition debris (cubic meters)[c]	220,000	220,000 - 440,000
Hazardous (cubic meters)	8,400	8,400 - 8,900
Sanitary and industrial solid (cubic meters)	100,000	110,000 - 170,000
Sanitary sewage (million liters)[d]	2,100	2,400 - 3,600
Industrial wastewater (million liters)	1,000	990 - 1,200
Low-level radioactive (cubic meters after treatment)	71,000	71,000 - 95,000

a. Totals for the construction, operation and monitoring, and closure phases.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. To convert cubic meters to cubic feet, multiply by 35.314.
d. To convert liters to gallons, multiply by 0.26418.

4.1.12.3 Impacts from Hazardous Materials

The operation of the Yucca Mountain Repository would require the use of hazardous materials including paints, solvents, adhesives, sodium hydroxide, dry carbon dioxide, aluminum sulfate, sulfuric acid, and compressed gases. DOE has programs and procedures in place to procure and manage hazardous materials (DIRS 104842-YMP 1996, all), ensuring their procurement in the appropriate quantities and storage under the proper conditions. At the repository, DOE would use an automated inventory management program (DIRS 104508-CRWMS M&O 1999, p. 62) to control and track inventory.

4.1.12.4 Waste Minimization and Pollution Prevention

DOE would develop a waste minimization and pollution prevention awareness plan similar to the plan it has used during site characterization activities at Yucca Mountain (DIRS 103203-YMP 1997, all). The goal of this new plan would be to minimize quantities of generated waste and to prevent pollution. To achieve this goal, DOE would establish requirements for each onsite organization and identify methods and activities to reduce waste quantities and toxicity.

DOE would recycle materials to the extent that it was cost-effective, feasible, and environmentally sound. Table 4-44 lists estimated quantities of materials that DOE would recycle during the life of the repository.

Table 4-44. Total recyclable material quantities generated for all phases.[a]

Material	Operating mode	
	Higher-temperature	Lower-temperature[b]
Recyclables (cubic meters)[c,d]	230,000	260,000 - 370,000
Steel (metric tons)[e]	51,000	51,000 - 240,000
Dual-purpose canisters[f] (cubic meters)	29,000	29,000
Oils and lubricants (liters)[g]	22 million	34 million - 67 million
Solar panels (metric tons)	1,700	1,700 - 5,700

a. Total for construction, operation and monitoring, and closure phases.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. Nonhazardous, nonradioactive materials such as paper, plastic, glass, and nonferrous metals.
d. To convert cubic meters to cubic feet, multiply by 35.314.
e. To convert metric tons to tons, multiply by 1.1023.
f. If dual-purpose canisters were used they would be recycled if appropriate, with regard to protection of the environment and cost-effectiveness. Estimated weight is 150,000 metric tons.
g. To convert liters to gallons, multiply by 0.26418.

DOE has identified pollution prevention opportunities in the repository conceptual design process. The Waste Treatment Building design includes recycling facilities for the large aqueous low-level radioactive waste stream [690,000 liters (182,000 gallons) per year for the uncanistered packaging scenario] (DIRS 100248-CRWMS M&O 1997, p. 23) that would result from decontamination activities. Wastewater recycling would greatly reduce water demand by repository facilities, as well as the amount of wastewater that would otherwise require disposal. In addition, DOE would use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would generate less waste than other techniques.

In addition, DOE would use automated maintenance tracking and inventory management programs that would interface with the procurement system (DIRS 104508-CRWMS M&O 1999, p. 62). These systems would assist in ensuring the proper maintenance of equipment through a preventive maintenance approach, which could lead to less waste generation. Inventory management would prevent overstocking that could allow chemicals and other items to exceed their shelf lives and become waste.

4.1.13 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, directs Federal agencies to identify and address the potential for their activities to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines and consideration of unique exposure pathways, sensitivities, and cultural practices to determine if disproportionately high and adverse impacts to human health or the environment of minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

DOE performs environmental justice analyses to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. *Disproportionately high and adverse human health effects* occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (DIRS 103162-CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (DIRS 103162-CEQ 1997, all).

The approach to environmental justice analysis first brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. On the basis of these analyses, DOE identified potential impacts on the general population. Second, based on available information, the approach assesses whether there are unique exposure pathways, sensitivities or cultural practices that would result in different impacts on minority or low-income populations. If potential impacts identified under either assessment would be high and adverse, the approach then compares the impacts on minority and low-income populations to those on the general population to determine whether any high and adverse impacts fall disproportionately on minority and low-income populations. In other words, if high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, no disproportionately high and adverse impacts would be expected. In making these determinations, DOE considers geographical areas that contain high percentages of minority or low-income populations as reported by the Bureau of the Census. As discussed in Chapter 3, Section 3.1.13, DOE used 2000 Census data for minority populations and 1990 Census data for low-income populations as the best, readily available information that would allow identification of the minority and low-income populations.

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (DIRS 103162-CEQ 1997, all)]. Nevada had a minority population of 34.8 percent in 2000. For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the to cause disproportionately high and adverse impacts to minority or low-income populations. This section uses the results of analyses from other disciplines and consideration of unique exposure pathways, sensitivities, and cultural practices to determine if disproportionately high and adverse impacts to human health or the environment of minority or low-income populations are likely to occur from repository performance confirmation, construction, operation and monitoring, and closure activities.

4.1.13.1 Methodology and Approach

DOE performs environmental justice analyses to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. The potential for environmental justice concerns exists if the following could occur:

- *Disproportionately high and adverse human health effects:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. *Disproportionately high and adverse human health effects* occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (DIRS 103162-CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (DIRS 103162-CEQ 1997, all).

The approach to environmental justice analysis first brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that in turn could affect human health or the environment. On the basis of these analyses, DOE identified potential impacts on the general population. Second, based on available information, the approach assesses whether there are unique exposure pathways, sensitivities or cultural practices that would result in different impacts on minority or low-income populations. If potential impacts identified under either assessment would be high and adverse, the approach then compares the impacts on minority and low-income populations to those on the general population to determine whether any high and adverse impacts fall disproportionately on minority and low-income populations. In other words, if high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, no disproportionately high and adverse impacts would be expected. In making these determinations, DOE considers geographical areas that contain high percentages of minority or low-income populations as reported by the Bureau of the Census. As discussed in Chapter 3, Section 3.1.13, DOE used 2000 Census data for minority populations and 1990 Census data for low-income populations as the best, readily available information that would allow identification of the minority and low-income populations.

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprised of a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population [for this EIS, a minority population is one in which the percent of the total population comprised of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (DIRS 103162-CEQ 1997, all)]. Nevada had a minority population of 34.8 percent in 2000. For this EIS, therefore, one focus of the environmental justice analysis is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) having a minority population of 44.8 percent or higher.

Nevada had a low-income population of 10 percent in 1990. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (DIRS 148189-Bureau of the Census 1999, all). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for construction, operation and monitoring, and closure of the proposed repository to have disproportionately high and adverse impacts on the populations in census block groups having a low-income population of 20 percent or higher.

In response to public comments, DOE has reevaluated available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations, even though the impacts to the general population would not be high and adverse. Several unique pathways or resources were identified and analyzed, although none revealed a potential for disproportionately high and adverse impacts (see Section 4.1.13.2).

4.1.13.2 Preconstruction Testing and Performance Confirmation, Construction, Operation and Monitoring, and Closure

Cultural Resources

DOE has implemented a worker education program on the protection of these resources to limit direct impacts to cultural resources, especially inadvertent damage and illicit artifact collecting. If significant data recovery (artifact collection) were required during construction and operation, DOE would initiate additional consultations with Native American Tribes to determine appropriate involvement. Further, archaeological resources and potential data recovery would be managed and conducted through consultations with the State Historic Preservation Officer or the Advisory Council on Historic Preservation.

Public Health and Safety

The EIS analyses determined that the impacts that could occur to public health and safety would be small on the population as a whole for all phases of the Proposed Action, and that no subsections of the population, including minority or low-income populations, would receive disproportionate impacts. The analysis considered an area that included Timbisha Shoshone Trust lands near Scottys Junction, Nevada.

Because contamination of edible plants and animals would be unlikely from construction, operation and monitoring, and eventual closure of the repository, impacts to persons leading subsistence lifestyles would be unlikely. During the period of construction, operation and monitoring, and closure of the proposed repository, the only radionuclides expected to be released would be naturally occurring radon and radon decay products, and noble gases. Of these, only radon decay products have the potential to accumulate in the environment in the edible portions of wild animals that might live within the land withdrawal area and later be consumed. DOE estimated the potential health impacts from a subsistence diet based primarily on game taken from lands proximate to the repository exclusion areas. DOE calculated the consequences of a 100 kilograms per year (approximately 220 pounds per year or 10 to 11 ounces per day over a year) ingestion of animals that had hypothetically experienced radon uptake. For the peak year, DOE calculated a 0.4 millirem increase in dose, which would have no adverse health effects. DOE concluded that no disproportionately high and adverse health and safety impacts would be likely. DOE also reviewed data on the potential for radioactive uptake from consumption of piñon nuts (DIRS 156058-Fresquez et al. 2000, all). Because piñon pine nuts are produced irregularly in 7- to 10-year cycles and radionuclide concentrations are very low in piñon pine trees and their edible portions, DOE concluded there would be little potential health impact. There would be no disproportionately high and adverse health and safety impacts.

Land Use

Direct land-use impacts from the Proposed Action would be low on members of the public because of the existing restriction on site access for most affected areas. There are no communities with high percentages of minority or low-income populations within the region of influence (see Chapter 3, Table 3-1).

Air Quality

Impacts to air quality from the Proposed Action would be small. Furthermore, DOE would use best management practices for all activities, particularly ground-disturbing activities that could generate fugitive dust and construction activities that could produce vehicle emissions. The analysis considered an area that included Timbisha Shoshone Trust lands near Scottys Junction, Nevada.

Biological Resources and Soils

Impacts to biological resources and soils would be low to nonexistent. Consequences for any resources of importance to minority or low-income communities would be small.

Socioeconomics

Because of the large population and employment in the region of influence, socioeconomic impacts from repository construction and operation would be small. During the construction phase and the operation and monitoring phase, regional employment would increase less than 0.5 percent above the baseline level (see Section 4.1.6.2.1). Changes to the baseline regional population would not be greater than 0.5 percent through 2033. The Proposed Action would generate minimal impacts to employment and population. Potential socioeconomic impacts of all other economic parameters analyzed (Gross Regional Product, real disposable income, and expenditures by State and local governments) would be small.

Noise

Impacts to sensitive noise receptors from the Proposed Action would not be likely because no sensitive noise receptors live in the Yucca Mountain region. Furthermore, there are no low-income or minority communities adjacent to the site.

4.1.13.3 Environmental Justice Impact Analysis Results

This analysis uses information from Sections 4.1.1 through 4.1.12. Those sections address impacts from all active phases of the Proposed Action—construction, operation and monitoring, and closure. As noted above, DOE expects that the impacts of the Proposed Action would be small on the population as a whole. DOE has not identified any subsection of the population, including minority and low-income populations, that would receive disproportionate impacts, and no unique exposure pathways, sensitivities, or cultural practices that would expose minority or low-income populations to disproportionately high and adverse impacts. Accordingly, DOE has concluded that no disproportionately high and adverse impacts would result from the Proposed Action.

4.1.13.4 A Native American Perspective

Native American tribal governments have a special and unique legal and political relationship with the Government of the United States, as established by treaty, statute, legal precedent, and the U.S. Constitution. For this reason DOE will continue to consult with tribal governments and will continue to work with representatives of the Consolidated Group of Tribes and Organizations to ensure the consideration of tribal rights and concerns before making decisions or implementing programs that affect such tribes; to continue the protection of Native American cultural resources, sacred sites, and potential traditional cultural properties; and to implement any appropriate mitigation measures.

In reaching the conclusion that there would be no disproportionately high and adverse impacts on minorities or low-income populations, DOE acknowledges that people from many Native American tribes have used the area proposed for the repository as well as nearby lands (DIRS 102043-AIWS 1998, p. 2-1), that the lands around the site contain cultural, animal, and plant resources important to those tribes, and that the implementation of the Proposed Action would continue restrictions on free access to the repository site. DOE acknowledges that Native American people living in the Yucca Mountain vicinity have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action.

Native American people living in the Yucca Mountain vicinity hold views and beliefs about the relationship between the proposed repository and the surrounding region that they have expressed in *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, all). Concerning the approach to daily life, the authors of that document, who represent the Western Shoshone, Owens Valley Paiute and Shoshone, Southern Paiute, and other Native American organizations, state:

> *…we have the responsibility to protect with care and teach the young the relationship of the existence of a nondestructive life on Mother Earth. This belief is the foundation for our holistic view of the cultural resources, i.e., water, animals, plants, air, geology, sacred sites, traditional cultural properties, and artifacts. Everything is considered to be interrelated and dependent on each other to sustain existence (DIRS 102043-AIWS 1998, p. 2-9).*

The authors discuss the cultural significance of Yucca Mountain lands to Native American people:

> *American Indian people who belong to the CGTO (Consolidated Group of Tribes and Organizations) consider the YMP lands to be as central to their lives today as they have been since the creation of their people. The YMP lands are part of the holy lands of Western Shoshone, Southern Paiute, and Owens Valley Paiute and Shoshone people (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *The lack of an abundance of artifacts and archaeological remains does not infer that the site was not used historically or presently and considered an integral part of the cultural ecosystem and landscape (DIRS 102043-AIWS 1998, p. 2-10).*

The authors address the continuing denial of access to Yucca Mountain lands:

> *One of the most detrimental consequences to the survival of American Indian culture, religion, and society has been the denial of free access to their traditional lands and resources (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *No other people have experienced similar cultural survival impacts due to lack of free access to the YMP area (DIRS 102043-AIWS 1998, p. 2-20).*

The authors recognize that past restrictions on access have resulted in generally beneficial and protective effects for cultural resources, sacred sites, and potential traditional cultural properties (DIRS

102043-AIWS 1998, Section 3.1.1). However, the authors express concerns of Native American people regarding use of the repository:

> *The past, present, and future pollution of these holy lands constitutes both Environmental Justice and equity violations. No other people have had their holy lands impacted by YMP-related activities (DIRS 102043-AIWS 1998, p. 2-20).*

and:

> *Access to culturally significant spiritual places and use of animals, plants, water and lands may cease because Indian people's perception of health and spiritual risks will increase if a repository is constructed (DIRS 102043-AIWS 1998, p. 3-1).*

Even after closure and reclamation, the presence of the repository would represent an irreversible impact to traditional lands and other elements of the natural environment in the view of Native American people.

Regarding the transportation of spent nuclear fuel and high-level radioactive waste, the authors state:

> *…health risks and environmental effects resulting from the construction and operation of the proposed intermodal transfer facility (ITF) and the transportation of high-level waste and spent nuclear fuel is considered by Indian people to be disproportionately high. This is attributed primarily to the consumption patterns of Indian people who still use these plants and animals for food, medicine, and other related cultural or ceremonial purposes (DIRS 102043-AIWS 1998, p. 2-19).*

and:

> *The anticipated additional noise and interference associated with an ITF* [Intermodal Transfer Facility] *and increased transportation may disrupt important ceremonies that help the plants, animals, and other important cultural resources flourish, or may negatively impact the solitude that is needed for healing or praying (DIRS 102043-AIWS 1998, p. 2-19).*

DOE recognizes that it could not undertake disposal of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain without conflict with the viewpoint expressed in the American Indian Writers Subgroup document, but believes that, should the repository be designated, DOE would have the opportunity to engage in regular consultations with representatives of tribes in the region to identify further measures to protect cultural resources, thereby lessening the concern expressed by Native American people.

4.1.14 IMPACTS OF REPOSITORY OPERATING MODES

This section briefly describes and compares the short-term environmental impacts for the range of repository operating modes considered as part of the Proposed Action. This range includes the higher-temperature operating mode [where postclosure repository temperatures could be above the boiling point of water (96°C, or 205°F) and the lower-temperature operating mode [where postclosure repository temperatures would remain below 85°C (185°F)]. The lower-temperature operating mode also includes a range of operating characteristics, and differences noted below describe the largest potential differences among the operating modes.

In general, the EIS analyses found the lower-temperature operating mode would have higher environmental impacts than the higher-temperature operating mode. At least partly responsible for this is the fact that the duration of the lower-temperature operating mode (171 to 341 years) would be longer than the duration of the higher-temperature operating mode (115 years). Any time-dependent impacts, such as health and safety impacts to populations or energy or material usage, are typically higher for the longer duration lower-temperature operating mode. Overall, impacts would be small. Some areas of specific interest:

- Short-term health and safety impacts to the public would be small, with those of the lower-temperature operating mode 2 to 4 times greater than the higher-temperature operating mode.
- Short-term health and safety impacts to workers would be small, with those of the lower-temperature operating mode up to 60 to 70 percent greater than the higher-temperature operating mode.
- Short-term impacts for the land use, ambient air quality, surface water, groundwater, biological resources and soil, cultural resources, socioeconomics, repository accidents, noise, aesthetics, utilities, energy, materials, waste generation, and environmental justice would be small.

A more complete comparison of potential impacts is shown in Section 2.4 and Table 2-7.

4.1.15 IMPACTS FROM MANUFACTURING REPOSITORY COMPONENTS

This section discusses the potential environmental impacts from the manufacturing of components required by the Proposed Action to dispose of spent nuclear fuel and high-level radioactive waste permanently at a monitored geologic repository at Yucca Mountain. Repository components include disposal containers, emplacement pallets, drip shields, dry storage cask shells, and shipping casks. The solar panels required for the solar power electric generating facility are standard commercially available components that DOE could buy from several vendors. Therefore, there would be no offsite manufacturing environmental impacts specifically attributed to the solar panels. This analysis considers transportation overpacks that would provide radiation shielding in the same manner as a shipping cask but that DOE would use only in conjunction with disposable canisters and dual-purpose canisters to be shipping casks without baskets or other internal configurations.

4.1.15.1 Overview

DOE followed the overall approach and analytical methods used for the environmental evaluation and the baseline data directly from the *Department of the Navy Final Environmental Impact Statement for a Container System for the Management of Naval Spent Nuclear Fuel* (DIRS 101941-USN 1996, all). DOE's evaluation focuses on ways in which the manufacture of the repository components could affect environmental attributes and resources at a representative manufacturing site. It is not site-specific because more than one manufacturer probably would be required to meet the production schedule requirements for component delivery, and the location of the companies chosen to manufacture these components is not known. The companies and, therefore, the actual manufacturing sites would be determined by competitive bidding.

The analysis used a representative manufacturing site based on five facilities that produce casks, canisters, and related hardware for the management of spent nuclear fuel. The concept of a representative site was used in the Navy EIS (DIRS 101941-USN 1996, p. 4-1), and the representative site used in this analysis was defined in the same way, using the same five existing manufacturing facilities with the same attributes. The facilities used to define the representative site are in Westminster, Massachusetts; Greensboro, North Carolina; Akron, Ohio; York, Pennsylvania; and Chattanooga, Tennessee (DIRS 101941-USN 1996, p. 4-17). All of these facilities make components for firms with cask and canister designs approved by the Nuclear Regulatory Commission.

The analysis assumed that the manufacturing facilities and processes being used are similar to the facilities and processes that would produce disposal containers, emplacement pallets, drip shields, dry storage cask shells, and shipping casks for the Yucca Mountain Repository. Although these five facilities might not fabricate components from titanium (the material required for the drip shields), the fabrication processes of rolling plate, forming, and welding necessary to produce a drip shield are similar to the processes used to manufacture casks and canisters from other structural material. The estimates for manufacturing time and component cost account for the differences in processing titanium components (for example, welding), so the impacts of manufacturing titanium components could be estimated using the same methods as those used for standard nuclear-grade components. The analysis considered the manufacturing processes used at these facilities and the total number of components required to implement each packaging scenario. Manufacture of all components was assumed to occur at one representative site, but DOE recognizes that it probably would occur at more than one site. The assumption of one manufacturing site is conservative (that is, it tends to overestimate impacts) because it concentrates the potential impacts.

In addition, the analysis of offsite manufacturing evaluated the use of materials and the potential for impacts to material markets and supplies.

Section 4.1.15.3 describes the components to be manufactured offsite. Section 4.1.15.4 discusses pertinent information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 describes environmental impacts on air quality, health and safety, socioeconomics, material use, waste generation, and environmental justice.

4.1.15.2 Components and Production Schedule

Table 4-45 lists the quantities of components analyzed for the higher- and lower-temperature operating modes for canistered and uncanistered packaging scenarios described in Chapter 2, Section 2.1.1. In general, the environmental impacts of offsite manufacturing are bounded by the uncanistered packaging scenario. The impacts of the canistered scenario are also presented to allow canistered and uncanistered comparisons. The only component with higher quantities under canistered scenarios would be rail shipping casks. Table 4-45 includes all repository components for naval spent nuclear fuel that would be emplaced in Yucca Mountain but does not include shipping casks for naval spent nuclear fuel. Shipping casks for naval spent nuclear fuel are owned and managed by the Navy. DIRS 101941-USN (1996, all) analyzed environmental impacts for production of naval spent nuclear fuel canisters and shipping casks. Because naval spent nuclear fuel waste packages represent less than 3 percent of the inventory to be emplaced in the repository, the production of naval spent nuclear fuel casks would add little to the impacts described in the following sections.

Table 4-45. Quantities of offsite-manufactured components for the Yucca Mountain Repository.[a]

		Operating mode/packaging scenario[b]			
		Higher-temperature		Lower-temperature	
Component	Description	UC	C	UC	C
Rail shipping casks or overpacks	Storage and shipment of SNF[c] and HLW[c]	0	92 or 120	0	92 or 120
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	120	8	120	8
Disposal containers		11,300	11,300	11,300 - 16,900	11,300 - 16,900
Emplacement pallet	Support for emplaced waste package	11,300	11,300	11,300 - 16,900	11,300 - 16,900
Drip shields	Titanium cover for a waste package	10,500	10,500	11,300 - 15,900	11,300 - 15,900
Solar panels[d]	Photovoltaic solar panels–commercial units	27,000	27,000	27,000	27,000
Dry storage cask shells[e]	Metal shell structure of storage vault for aging	0	0	0 - 4,000	0 - 4,000

a. The number of containers is an approximation but is based on the best available estimates.
b. UC = uncanistered; C = canistered.
c. SNF = spent nuclear fuel; HLW = high-level radioactive waste.
d. Number of panels in use at any one time.
e. Necessary only for commercial spent nuclear fuel and only if DOE used surface aging as part of a lower-temperature operating mode.

As currently planned, all of the components listed in Table 4-45 except drip shields would be manufactured over 24 years to support emplacement in the repository. Manufacturing activity would build up during the first 5 years, then would remain nearly constant through the remainder of the 24-year period. The drip shields would not be needed until the closure of the repository; therefore, the analysis assumed manufacture and delivery of drip shields would not begin until nearly 76 to 300 years after the completion of emplacement. It would take approximately 10 years to manufacture drip shields. The solar power generating facility would be built over a 6-year period beginning in 2005 (DIRS 153882-Griffith 2001, p. 6).

The dry storage cask shells would be needed only if surface aging were to be used in conjunction with the lower-temperature operating mode. Because surface aging would occur in parallel with emplacement, the dry storage cask shells would be manufactured in the same 24-year period as the disposal containers, emplacement pallets, and shipping casks.

4.1.15.3 Components

Disposal Containers

The disposal container would be the final outside container used to package the spent nuclear fuel and high-level radioactive waste emplaced in the repository. The basic design calls for a cylindrical vessel with an outer layer of corrosion-resistant nickel-based alloy (Alloy-22) and an inner liner of stainless steel Type 316NG. The inner and outer lids would be stainless steel Type 316NG and Alloy-22, respectively. An additional Alloy-22 lid would be installed on the closure end. The bottom lids would be welded to the cylindrical body at the fabrication shop, and the top inner and outer lids would be welded in place after the placement of spent nuclear fuel or high-level radioactive waste in the container at the repository. About 10 different disposal container designs would be used for different types of spent nuclear fuel and high-level radioactive waste. The designs would vary in length from 3.6 to 6.1 meters (11.8 to 20 feet) and the outside diameters would range from 1.3 to 2.1 meters (4.3 to 6.6 feet). In addition, the internal configurations of the containers would be different to accommodate different uncanistered spent nuclear fuel configurations and a variety of spent nuclear fuel and high-level radioactive waste disposable canisters. The mass of an empty disposal container would range from about 19 to 33 metric tons (21 to 36 tons). If surface aging was used as part of the lower-temperature operating mode, containers used for aging are assumed to be stainless steel Type 316NG.

Casks for Rail and Legal-Weight Truck Shipments

DOE would use two basic kinds of shipping cask designs—rail and truck—to ship spent nuclear fuel and high-level radioactive waste to the repository. The design of a specific cask would be tailored to the type of material it would contain. For example, rail and truck casks that could be used to ship commercial spent nuclear fuel would be constructed of stainless- or carbon-steel plate materials formed into cylinders and assembled to form inner and outer cylinders (DIRS 101941-USN 1996, p. 4-3 and 4-4). A depleted uranium or lead liner would be installed between the stainless- or carbon-steel cylinders, and a vessel bottom with lead or depleted uranium between the inner and outer stainless- or carbon-steel plates would be welded to the cylinders. A support structure that could contain neutron-absorbing material would be welded into the inner liner, if required. A polypropylene sheath would be placed around the outside of the cylinder for neutron shielding. After spent nuclear fuel assemblies were inserted into the cask, a cover with lead or depleted uranium shielding would be bolted to the top of the cylinder to close and seal it. Transportation overpacks would be very similar in design and construction to shipping casks but would not have an internal support structure for the spent nuclear fuel because they would be used only for dual-purpose or disposable canisters.

For commercial spent nuclear fuel, casks and overpacks are typically 4.5 to 6 meters (15 to 20 feet) long and about 0.5 to 2 meters (1.6 to 6.6 feet) in diameter. These casks are designed to be horizontal when shipped. Empty truck casks typically weigh from 21 to 22 metric tons (about 23 to 24 tons). Empty rail casks (or overpacks) for commercial spent nuclear fuel typically weigh from 59 to 91 metric tons (65 tons to a little over 100 tons). The corresponding weights when loaded with spent nuclear fuel range between 22 and 24 metric tons (24 and 26 tons) for truck casks and between 64 and 110 metric tons (70 and 120 tons) for rail casks. For protection during shipment, large removable impact limiters of aluminum honeycomb or other crushable impact-absorbing material would be placed over the ends (DIRS 101837-JAI 1996, all).

Emplacement Pallets

The emplacement pallet would support the waste packages emplaced and allow end-to-end placement of waste packages to within 10 centimeters (4 inches) of each other. The emplacement pallet would be shorter than the waste package so it would not interfere with close placement. The pallets would be fabricated from Alloy-22 plates welded together to form a V-shaped top surface, which would accept all waste package diameters, and two Alloy-22 supports. Stainless steel Type 316L tubes would connect the two emplacement Alloy-22 supports. Two pallet overall lengths are specified for emplacement support of all waste package designs. The shorter emplacement pallet [2.5 meters (8 feet)] would be used for the waste package containing DOE spent nuclear fuel and high-level radioactive waste and the longer emplacement pallet [4.2 meters (14 feet)] would be used for all other waste package designs. The mass of a short pallet and a long pallet is 1.8 and 2.1 metric tons (2 and 2.2 tons), respectively.

Drip Shields

The drip shield would be a rigid structure designed to divert water away from the waste packages. The drip shield would be fabricated from titanium Grade 7 plates for the water diversion surface, titanium Grade 24 for the structural members, and Alloy-22 for the feet. The Alloy-22 feet would be mechanically attached to the titanium drip shield side plates, since the two materials cannot be welded together. For the higher-temperature operating mode and the lower-temperature operating modes with waste package spacing of less than 1.6 meters (5 feet), a continuous design drip shield would be used. The continuous design drip shield would be installed in sections, with one end designed to overlap and interlock with the opposite end of the previously emplaced drip shield section. The continuous drip shield section would be 6.1 meters (20 feet) long by 2.5 meters (8 feet) wide by 6.1 meters (20 feet) high with a mass of 4.2 metric tons (4.6 tons).

For the lower-temperature operating mode, as waste package spacing increased it might become economical to use a freestanding enclosed drip shield design (DIRS 152808-Skorska 2000, all). The freestanding drip shield would be designed in two lengths, one shorter version [3.9-meter (13-foot) length] for the waste package containing DOE spent nuclear fuel and high-level radioactive waste and one longer version [6.4-meter (20-foot) length] for all other waste package designs. The ends of these drip shields would be partially enclosed. The materials used for the freestanding drip shield design would be the same as for the continuous design drip shield. The mass of a short drip shield and a long drip shield is 3.1 metric tons (3.4 tons) and 4.55 metric tons (5 tons), respectively.

Dry Storage Cask Shells

The dry storage cask shell would be fabricated from carbon steel. The shell would be the portion of the concrete dry storage cask system (used only for surface aging under the lower-temperature operating mode) that would be manufactured offsite. Each shell, which includes a base structure, would be approximately 3.4 meters (11 feet) in diameter by 5.9 meters (19 feet) high and would be made from thick carbon steel plate. Carbon steel plate would be formed into a cylinder to form the shell and carbon plate material would be welded to the shell cylinder to form the base structure of the shell. The shell would weigh about 44 metric tons (49 tons).

4.1.15.4 Existing Environmental Settings at Manufacturing Facilities

Because there are facilities that could meet the projected manufacturing requirements, the assessment concluded that no new construction would be necessary and that there would be no change in land use for the offsite manufacture of repository components. Similarly, cultural, aesthetic, and scenic resources would remain unaffected. Ecological resources, including wetlands, would not be affected because existing facilities could accommodate the manufacture of repository components and new or expanded facilities would not be required. Some minor increases in noise, traffic, or utilities would be likely, but none of these increases would result in impacts on the local environment.

Water consumption and effluent discharge during the manufacture of components would be typical of a heavy manufacturing facility and would represent only a small change, if any, from existing rates. Similarly, effluent discharges would not increase enough to cause difficulty in complying with applicable local, state, and Federal regulatory limits, and would be unlikely to result in a discernible increase in pollutant activity.

Accordingly, the following paragraphs contain information on environmental settings for air quality, health and safety, and socioeconomics. Section 4.1.15.5 evaluates the environmental impacts to these resource areas for a representative site.

Air Quality

The analysis evaluated the ambient air quality status of the representative manufacturing location by examining the air quality of the areas in which the reference manufacturing facilities are located. The principal criteria pollutants for cask manufacturing facilities are ozone, carbon monoxide, and particulate matter (PM_{10}). Areas where ambient air quality standards are not exceeded, or where measurements have not been made, are considered to be in attainment. Areas where the air quality violates Federal or state regulations are in nonattainment and subject to more stringent regulations. Typical existing container and cask manufacturing facilities are in nonattainment areas for ozone and in attainment areas for carbon monoxide and particulate matter.

Because most of the existing typical manufacturing facilities are in nonattainment areas for ozone, the analysis assumed that the representative site would be in nonattainment for ozone and that ozone would be the criteria pollutant of interest. Volatile organic compounds and nitrous oxides are precursors for ozone and are indicators of likely ozone production. For the areas in which the reference manufacturing facilities are located, an average of 3,400 metric tons (approximately 3,800 tons) of volatile organic compounds and 39,000 metric tons (approximately 43,000 tons) of nitrous oxides were released to the environment in 1990 (DIRS 101941-USN 1996, p. 4-5).

Health and Safety

Data on the number of accidents and fatalities associated with cask and canister fabrication at the representative manufacturing location were based on national incidence rates for the relevant sector of the economy. In 1992, the occupational fatality rate for the sector that includes all manufacturing was 3 per 100,000 workers; the occupational illness and injury rate for fabricated plate work manufacturing in 1992 was 6.3 per 100 full-time workers (DIRS 101941-USN 1996, p. 4-5).

The manufacture of hardware for each of the operating modes and packaging scenarios would be likely to be in facilities that have had years of experience in rolling, shaping, and welding metal forms, and then fabricating large containment vessels similar to the required repository components for nuclear materials. Machining operations at these facilities would involve standard procedures using established metalworking equipment and techniques. Trained personnel familiar with the manufacture of large, multiwall, metal containment vessels would use the equipment necessary to fabricate such items. Because of this experience and training, DOE anticipates that the injury and illness rate would be equal to or lower than the industry rates.

Socioeconomics

Each of the five manufacturing facilities examined in this analysis is in a Metropolitan Statistical Area or a Primary Statistical Area, as defined by the U.S. Bureau of the Census. The counties comprising each statistical area define the affected socioeconomic environment for each facility. The populations of the affected environments associated with the five facilities ranged from about 373,000 to 1.2 million in 1998 (DIRS 156775-Bureau of the Census 2001, p. 33). In 1995, output (the value of goods and services produced in the five locations) ranged from $18 billion to $55 billion. The income (wages, salaries, and property income) ranged from $9 billion to $26 billion, area employment ranged from 245,000 to 670,000 workers in 1995, and plant employment ranged from 25 to 995 (DIRS 101941-USN 1996, p. 4-6). Based on averages of this information, the representative manufacturing location has a population of about 690,000 and the representative plant employs 480. Local output in the area is $30 billion, local income is $15 billion, and local employment is 390,000.

4.1.15.5 Environmental Impacts

As mentioned in Section 4.1.15.4, this evaluation considered only existing manufacturing facilities, so environmental impact analyses are limited to air quality, health and safety, waste generation, and socioeconomics. Impacts are presented for the higher-temperature operating mode and a range of impacts are presented for the lower-temperature operating mode. In addition, this section contains a discussion of environmental justice.

4.1.15.5.1 *Air Quality*

The analysis used the baseline data and methods developed in DIRS 101941-USN (1996, Section 4.3) to estimate air emissions from manufacturing sites for the production of repository components. Criteria pollutants and hazardous air pollutants were considered, and predicted emissions were compared with typical regional or county-wide emissions to determine potential impacts of the emissions on local air quality.

Potential emissions were evaluated for a representative manufacturing location using the ambient air quality characteristics of typical manufacturing facilities, as described in Section 4.1.15.4. The analysis assumed that the representative location used for this analysis would be in a nonattainment area for ozone and in attainment areas for carbon monoxide and particulate matter. Therefore, ozone was the only criteria pollutant analyzed. Ozone is not normally released directly to the atmosphere, but is produced in a complex reaction of precursor chemicals (volatile organic compounds and nitrous oxides) and sunlight. This section evaluates the emissions of these precursors.

The reference air emissions associated with the manufacture of repository components were developed using the emissions resulting from manufacturing similar components (DIRS 101941-USN 1996, p. 4-6) and were normalized based on the number of work hours required for the manufacturing process. The analysis prorated these reference emissions on a per-unit basis to calculate annual emissions at the reference manufacturing site, assuming emissions from similar activities would be proportional to the number of work hours in the manufacturing process. To provide reasonable estimates of emissions, the analysis assumed that the volatile organic compounds used as cleaning fluids would evaporate fully into the atmosphere as a result of the cleaning processes used in manufacturing. The estimates of emissions were based on the total number of repository components manufactured over a 10-year period for drip shields and a 24-year period for all other components.

Table 4-46 lists the estimated annual average and estimated total emissions from the manufacture of components at the representative facility for each packaging scenario. Estimated annual average emissions of volatile organic compounds would vary from 1.0 to 1.5 metric tons (approximately 1.1 to 1.5 tons) a year for the 24-year period and from 0.59 to 0.89 metric ton (approximately 0.65 to 0.98 ton) for the 10-year drip shield manufacturing period. Nitrous oxide emissions vary from 1.3 to 1.9 metric tons (approximately 1.4 to 1.8 tons) a year for the 24-year period and from 0.76 to 1.2 metric tons (approximately 0.79 to 1.2 tons) for the 10-year drip shield manufacturing period. Annual average emissions from component manufacturing under any of the scenarios would be less than 0.05 percent of

Table 4-46. Ozone-related air emissions (metric tons)[a] at the representative manufacturing location.

		Operating mode/packaging scenario[b]		
		UC	DPC	UC/DPC/DISP
Compound	Measure	HT	HT	LT[c]
Volatile organic compounds				
24-year period[d]	Annual average	1.0	1.0	1.0 - 1.5
	24-year total	25	26	25 - 35
	Percent of *de minimis*[e]	11	12	11 - 16
10-year period[f]	Annual average	0.59	0.59	0.65 - 0.89
	10-year total	5.9	5.9	6.5 - 8.9
	Percent of *de minimis*	6.5	6.5	7.1 - 9.8
Nitrogen oxides				
24-year period	Annual average	1.3	1.4	1.3 - 1.9
	24-year total	32	33	32 - 46
	Percent of *de minimis*	15	15	15 - 21
10-year period	Annual average	0.76	0.76	0.85 - 1.2
	10-year total	7.6	7.6	8.5 - 12
	Percent of *de minimis*	8.4	8.4	9.3 - 13

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = *dual-purpose canister*; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
d. The 24-year manufacturing period is for all components except drip shields and begins 2 years prior to emplacement.
e. *De minimis* level for an air quality region in extreme nonattainment for ozone is 9.1 metric tons per year of volatile organic compounds or nitrogen oxides (40 CFR 51.853).
f. The 10-year manufacturing period is for drip shields only and occurs at repository closure.

regional emissions of volatile organic compounds and 0.005 percent of regional emissions of nitrous oxides. Emissions from the manufacture of repository components would contain a relatively small amount of ozone precursors compared to other sources.

The examination assumed that the emissions of volatile organic compounds and nitrous oxides were new sources; these emissions were compared with emission threshold levels (emission levels below which conformity regulations do not apply). There are different categories of ozone nonattainment areas based on the sources of ozone and amount of air pollution in the region. The different categories have different emission threshold levels (40 CFR 51.853).

For an air quality region to be in extreme nonattainment for ozone (most restrictive levels), the emission threshold level for both volatile organic compounds and nitrous oxides is 9.1 metric tons (10 tons) per year. Table 4-46 also lists the percentage of volatile organic compounds and nitrous oxides from the manufacture of repository components in relation to the emission threshold level of an extreme ozone nonattainment area. Annual air emissions from the manufacture of repository components would vary depending on the operating mode and packaging scenario, with ranges of 6.5 to 16 percent and 8.4 to 21 percent of the emission threshold levels for volatile organic compounds and nitrous oxides, respectively. In all of the packaging scenarios, component manufacturing would not be likely to fall under the conformity regulations because the predicted emissions of volatile organic compounds and nitrous oxides would be well below (less than 21 percent of) the emission threshold level of 9.1 metric tons per year. However, DOE would ensure the implementation of the appropriate conformity determination processes and written documentation for each designated manufacturing facility.

States with nonattainment areas for ozone could place requirements on many stationary pollution sources to achieve attainment in the future. This could include a variety of controls on emissions of volatile organic compounds and nitrous oxides. Various options such as additional scrubbers, afterburners, or carbon filters would be available to control emissions of these compounds to comply with limitations.

4.1.15.5.2 *Health and Safety*

The analysis used data on the metal fabrication and welding industries from the Bureau of Labor Statistics to compile baseline occupational health and safety information for industries that fabricate steel and steel objects similar to the repository components (DIRS 101941-USN 1996, p. 4-8). The expected number of injuries and fatalities were computed by multiplying the number of work years by the injury and fatality rate for each occupation.

Table 4-47 lists the expected number of injuries and illnesses and fatalities for each scenario based on the work years required to produce the number of components. Injuries and illnesses would range from 580 to 840, depending on the operating mode and packaging scenario. Fatalities would be unlikely.

Table 4-47. Occupational injuries, illness, and fatalities at the representative manufacturing location.[a]

	Operating mode/packaging scenario		
	Higher-temperature		Lower-temperature[b]
Parameter	UC	DPC	UC/DPC/DISP[c]
Injuries and illnesses	580	600	600 - 840
Fatalities	0.28	0.28	0.28 - 0.40

a. Impacts from 24 years for manufacture for all components except drip shields and 10 years for manufacture of drip shields.
b. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
c. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.

The required number of repository components would not place unusual demands on existing manufacturing facilities. Thus, none of the scenarios would be likely to lead to a deterioration of worker safety and a resultant increase in accidents. In addition, nuclear-grade components are typically built to higher standards and with methods that are more proceduralized, both of which lead to improved worker safety.

4.1.15.5.3 *Socioeconomics*

The assessment of socioeconomic impacts from manufacturing activities involved three elements:

- Per-unit cost data for disposal containers, emplacement pallets, and drip shields (DIRS 150558-CRWMS M&O 2000, all) and per-unit cost of shipping casks (DIRS 104967-CRWMS M&O 1998, Table 12, pp. 17 and 18)

- Total number of components

- Economic data for the environmental setting for each facility to calculate the direct and secondary economic impacts of repository component manufacturing on the local economy (DIRS 103074-BEA 1992, all)

  – The local economy would be directly affected as manufacturing facilities purchased materials, services, and labor required for manufacturing.

  – The local economy would also experience secondary effects as industries and households supplying the industries that were directly affected adjusted their own production and spending behavior in response to increased production and income, thereby generating additional socioeconomic impacts.

Impacts were measured in terms of output (the value of goods and services produced), income (wages, salaries, and property income), and employment (number of jobs).

The socioeconomic analysis of manufacturing used state-level economic multipliers for fabricated metal products (DIRS 103074-BEA 1992, all). To perform the analysis, DOE obtained the product, income, and employment multipliers for the states where the five existing manufacturing facilities are located. (Multipliers account for the secondary effects on an area's economy in addition to providing direct effects on its economy). The multipliers were averaged to produce composite multipliers for a representative manufacturing location. The composite multipliers were used to analyze the impacts of each alternative. Table 4-48 lists the state-specific multipliers and the composite multipliers.

Table 4-48. Economic multipliers for fabricated metal products.[a]

State	Final demand multiplier ($)		Direct effect multiplier (number of jobs)
	Products	Earnings	
Massachusetts	1.8927	0.5555	2.2050
North Carolina	1.9145	0.5426	2.1544
Ohio	2.6019	0.7260	3.1064
Pennsylvania	2.5697	0.7194	2.8552
Tennessee	2.1379	0.6107	2.5314
Composite	2.2233	0.6308	2.5705

a. Source: DIRS 103158-Bureau of the Census (1992, all).

The analysis was limited to estimating the direct and secondary impacts of manufacturing activities. No assessment was made of the impacts of manufacturing activities on local jurisdictions. Such an analysis would include the estimation of impacts on county and municipal government and school district revenues and expenditures. Because the production of repository components probably would occur at existing facilities alongside existing product lines, a substantial population increase due to workers moving into the vicinity of the manufacturing sites in a given year under any scenario would be unlikely. Due to this lack of demographic impacts, meaningful change in the disposition of local government or school district revenues and expenditures would be unlikely. Because substantial population increases would not be likely, the analysis did not consider impacts on other areas of socioeconomic concern, such as housing and public services.

The analysis calculated average annual impacts for the manufacturing period of 10 years for drip shields and 24 years for all other components. The impacts of each packaging scenario were compared to the baseline at the representative location in 1995, with results expressed in millions of 2001 dollars. No attempt was made to forecast local economic growth or inflation rates for each representative location because of the non-site-specific nature of the analysis.

Table 4-49 lists the impacts of each operating mode and packaging scenario on output, income, and employment at the representative manufacturing location. The impacts include the percent of each scenario in relation to overall output, income, and employment in the economy.

Local Output

The average annual output impacts of each scenario would range from about $620 million to about $1,200 million (Table 4-48) depending on the operating mode and packaging scenario. Output generated from each scenario would increase total local output from between 1.8 percent and 2.4 percent, on average, over the 24-year manufacturing period, and from between 2.4 percent and 3.5 percent over the 10-year drip shield manufacturing period.

Table 4-49. Socioeconomic impacts for operating modes and packaging scenarios at the representative manufacturing location.

Flexible design/ packaging scenario[a]	Average annual output[b]		Average annual income		Average annual employment	
	$ (millions)	Percent impact[c]	$ (millions)	Percent impact	Person-years	Percent impact
UC						
HT 24-year period[d]	620	1.8	180	1.1	800	0.21
HT 10-year period[e]	810	2.4	230	1.4	460	0.12
DPC						
HT 24-year period	630	1.8	180	1.1	820	0.21
HT 10-year period	810	2.4	230	1.4	460	0.12
UC/DPC/DISP[f]						
LT 24-year period	620 - 790	1.8 - 2.3	180 - 220	1.1 - 1.3	800 - 1,100	0.21 - 0.29
LT 10-year period	1,000 - 1,200	2.9 - 3.5	290 - 350	1.7 - 2.1	510 - 690	0.13 - 0.18

a. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
b. Annual output and income impacts are expressed as millions of 2001 dollars.
c. Percent impact refers to the percentage of the baseline data discussed in Section 4.1.15.4 for the representative site, escalated to 2001 dollars.
d. The 24-year manufacturing period is for all components except drip shields and begins two years prior to emplacement.
e. The 10-year manufacturing period is for drip shields only and occurs at repository closure.
f. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.

Local Income

The average annual income impacts of each packaging scenario would range from about $180 million to about $350 million (Table 4-48) depending on the operating mode and packaging scenario. Income generated from each scenario would increase total local income between 1.1 percent and 1.3 percent over the 24-year manufacturing period and from between 1.4 percent and 2.1 percent over the 10-year drip shield manufacturing period.

Local Employment

The average annual employment impacts of each packaging scenario would range from about 460 to about 1,100 work years (Table 4-48), depending on the operating mode and packaging scenario. Employment generated from any of the scenarios would increase total local employment about 0.22 percent, on average, over the 24-year manufacturing period and about 0.14 percent, on average, over the 10-year drip shield manufacturing period.

4.1.15.5.4 *Impacts on Material Use*

To the extent available, DOE based the calculations of the quantities of materials it would use for the manufacture of each component on engineering specifications for each hardware component. This information was provided by the manufacturers of systems either designed or under licensing review (DIRS 101941-USN 1996, Sections 3.0 and 4.1.1; DIRS 150558-CRWMS M&O 2000, all; DIRS 102030-CRWMS M&O 1999, all), or from conceptual design specifications for technologies still in the planning stages (DIRS 101837-JAI 1996, all). Data on per-unit material quantities for each component were combined with information on the number of components to be manufactured for each operating mode and packaging scenario. In addition, the analysis assessed the impact of component manufacturing for each scenario on the total U.S. production (or availability in the United States, if not produced in this country) of each relevant input material. The results of the assessment are expressed in terms of percent impacts on total U.S. domestic production of most commodities.

Table 4-50 lists estimated total quantities of materials that DOE would need for each packaging scenario along with the annual average requirement for each material. For each scenario the largest material

Table 4-50. Material use (metric tons).[a]

Material	Higher-temperature UC Total	Higher-temperature UC Annual	Higher-temperature DPC Total	Higher-temperature DPC Annual	Lower-temperature UC/DPC/DISP[c] Total	Lower-temperature UC/DPC/DISP[c] Annual
	Basic material use per operating mode/packaging scenario[b]					
Aluminum	2,600	110	2,600	110	90 - 2,600	4 - 110
Chromium[d]	52,000	2,200	52,000	2,200	52,000 - 63,000	2,200 - 2,600
Copper	36	1	73	3	36 - 140	1 - 6
Depleted uranium	880	37	88	4	88-1,400	4 - 60
Lead	430	18	3,300	140	430 - 3,300	18 - 140
Molybdenum[e]	14,000	600	14,000	600	14,000 - 17,000	600 - 700
Nickel[f]	82,000	3,400	83,000	3,500	83,000 - 100,000	3,500 - 4,200
Steel[g]	150,000	6,300	150,000	6,300	150,000 - 330,000	6,300 - 14,000
Titanium	43,000	4,300	43,000	4,300	54,000 - 65,000	5,400 - 6,500

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the disposable canister packaging scenario.
d. Chromium estimated as 18 percent of stainless steel and 22 percent of nickel base alloy.
e. Molybdenum estimated as 13.5 percent of nickel base alloy.
f. Nickel estimated as 58 percent of nickel base alloy and 14 percent of stainless steel.
g. Steel estimated as 100 percent of carbon steel and 52 percent of stainless steel.

requirement by weight would be steel, ranging from about 150,000 to about 330,000 metric tons (160,000 to 360,000 tons), depending on the operating mode and packaging scenario.

Table 4-51 compares the annual U.S. production capacity to the annual requirements for the materials each scenario would use. With the exception of chromium, nickel, and titanium, consumption for each scenario would be less than 1.5 percent of the annual U.S. production.

Table 4-51. Annual amount (metric tons)[a] of material required for manufacturing, expressed as a percent of annual U.S. domestic production.

Material	Production[d,e,f]	Higher-temperature UC Annual	Higher-temperature UC Percent	Higher-temperature DPC Annual	Higher-temperature DPC Percent	Lower-temperature UC/DPC/DISP[c] Annual (max)[g]	Lower-temperature UC/DPC/DISP[c] Percent
		Basic material use per flexible design operating mode/packaging scenario[b]					
Aluminum	5,000,000	110	0.002	110	0.002	110	0.002
Chromium	104,000	2,200	2.1	2,200	2.1	2,600	2.5
Copper	1,900,000	1	0.0001	3	0.0002	6	0.0003
Depleted uranium	14,700	37	0.25	4	0.03	60	0.41
Lead	430,000	18	0.004	140	0.03	140	0.03
Molybdenum	57,000	600	1.05	600	1.1	700	1.2
Nickel	14,600	3,400	23	3,500	24	4,200	29
Steel	91,500,000	6,300	0.007	6,300	0.007	14,000	0.01
Titanium	22,000	4,300	20	4,300	20	6,500	30

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister; HT = higher-temperature operating mode; LT = lower-temperature operating mode.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the disposable canister packaging scenario.
d. Source: DIRS 103156-Bureau of the Census (1997, Table 1155, p. 700, and Table 1244, p. 756).
e. Source for depleted uranium production: DIRS 101941-USN (1996, p. 4-10).
f. Source for titanium production: DIRS 152457-Gambogi (1999, Volume 1, Table 2, p. 80.7).
g. Maximum from range for lower-temperature operating modes is reported here.

Therefore, the use of aluminum, copper, lead, molybdenum, depleted uranium or steel would not produce a noteworthy increased demand and should not have a meaningful effect on the supply of these materials.

The annual requirement for chromium as a component in stainless-steel and high-nickel alloy ranges from about 2.12 percent to about 2.5 percent of the annual U.S. production, depending on the flexible design operating mode and packaging scenario. Most chromium, which is an important constituent of many types of stainless steel, is imported into the United States and is classified as a Federal Strategic and Critical Inventory material. For comparative purposes, the maximum total requirement of about 63,000 metric tons (69,000 tons) can be evaluated as a percentage of the 1994 strategic chromium inventory of 1.04 million metric tons (1.15 million tons) (DIRS 103156-Bureau of the Census 1997, Table 1159, p. 702). The total repository program need would be about 6 percent of the strategic inventory. With the strategic inventory to support the program demand, chromium use should not cause any market or supply impacts.

Annual nickel use as a component in stainless steel and corrosion-resistant high-nickel alloys appears, relatively, the most important in comparison to U.S. production. The magnitude of the comparison is the result of low U.S. production because the United States imports most of the nickel it uses. Although the annual U.S. production of nickel is only 14,600 metric tons (16,100 tons), the annual U.S. consumption is 158,000 metric tons (174,000 tons) (DIRS 103156-Bureau of the Census 1997, Table 1155, p. 700). This annual consumption is supported by a robust world production of 1.04 million metric tons (1.15 million tons) (DIRS 103156-Bureau of the Census 1997, Table 1158, p. 702). The maximum annual program need is a little less than 3 percent of the U.S. consumption and about 0.5 percent of world production. Canada is a major world supplier of nickel. DOE does not anticipate that the maximum program demand would affect the U.S. or world nickel markets.

The annual amount of depleted uranium used over 24 years would range from 0.25 percent to 0.41 percent of the total U.S. annual production. These requirements would be small. Given the limited alternative uses of this material and the large current inventory of surplus depleted uranium hexafluoride owned by DOE, such impacts should be considered to be positive (DIRS 101941-USN 1996, p. 4-10). Lead or steel could be substituted for depleted uranium for radiation shielding in some cases. If those materials were used for this purpose, the thickness of the substituted material would increase in inverse proportion to the ratio of the density of the substituted material to the density of depleted uranium. If lead or steel were used, the shielding thickness would increase by about 170 percent or 240 percent, respectively, resulting in a much larger container (DIRS 101941-USN 1996, p. 4-10).

The annual requirement for titanium for drip shields ranges from about 4,300 to 6,500 metric tons (4,740 to 7,165 tons), depending on the operating mode and packaging scenario. The magnitude of the comparison is the result of low U.S. production of the basic raw material, because the United States imports most of the titanium raw material. Although the annual U.S. production of titanium raw material is only 21,600 metric tons (23,810 tons), the annual U.S. capacity to produce titanium ingots is 78,200 metric tons (86,200 tons) (DIRS 152457-Gambogi 1999, p. 80.7). The maximum annual program need is a little over 8 percent of the current annual U.S. ingot production. Titanium is classified as a Federal Strategic and Critical Inventory material and is the ninth most common element in the Earth's crust (DIRS 107031-U.S. Bureau of Mines 1985, p. 859). Because the drip shields would not be needed until repository closure, there would be adequate time (over 100 years) to complete production of titanium raw material or to import additional raw material in advance of the need to reduce impact on markets.

4.1.15.5.5 *Impacts of Waste Generation*

The component materials used in the manufacture of repository components would be carbon steel, high-nickel alloy, stainless steel, aluminum, copper, and titanium with either depleted uranium or lead used for shielding. The manufacture of shielding would generate hazardous or low-level radioactive waste, depending on the material used. Other organic and inorganic chemical wastes generated by the manufacture of repository components and the amounts generated have also been identified.

Based on data in DIRS 101941-USN (1996, p. 4-13), the analysis estimated annual volumes and quantities of waste produced for each scenario per component manufactured at the representative site. The potential for impacts was evaluated in terms of existing and projected waste handling and disposal procedures and regulations. In addition to relevant state regulatory agencies, the Environmental Protection Agency and the Occupational Safety and Health Administration regulate the manufacturing facilities.

Manufacturing to support the different flexible design operating modes and packaging scenarios would produce liquid and solid wastes at the manufacturing locations. To control the volume and toxicity of these wastes, manufacturers would comply with existing regulations. Pollution prevention and reduction practices would be implemented. The analysis evaluated only waste created as a result of the manufacturing process to produce repository components from component materials. It did not consider the waste produced in mining, refining, and processing raw materials into component materials for distribution to the manufacturer. The analysis assumed that the component materials, or equivalent component materials produced from the same raw materials, would be available from supplier stock, which would be available without regard to the status of the Yucca Mountain project.

Liquid Waste

The liquid waste produced during manufacturing would consist of used lubricating and cutting oils from machining operations and the cooling of cutting equipment. This material is currently recycled for reuse. Ultrasonic weld testing would generate some unpotable water-containing glycerin. Water used for cooling and washing operations would be treated for release by filtration and *ion* exchange, which would remove contaminants and permit discharge of the treated water to the sanitary system.

Table 4-52 lists the estimated amounts of liquid waste generated by the shaping, machining, and welding of the components required for each scenario. The annual average amount of liquid waste generated would range from 4.1 to 6.4 metric tons (approximately 4.5 to 7.0 tons) per year during either the 24-year or 10-year manufacturing periods. The small quantities of waste produced during manufacturing would not exceed the capacities of the existing equipment for waste stream treatment at the manufacturing facility.

Table 4-52. Annual average waste generated (metric tons)[a] at the representative manufacturing location.

		Operating mode/packaging scenario[b]		
		Higher-temperature		Lower-temperature
Compound	Measure	UC	DPC	UC/DPC/DISP[c]
Liquid				
24-year period[d]	Annual average	4.3	4.3	4.3 - 6.4
10-year period[e]	Annual average	4.1	4.1	4.4 - 6.2
Solid				
24-year period[d]	Annual average	0.59	0.59	0.59 - 0.88
10-year period[e]	Annual average	0.57	0.57	0.61 - 0.86

a. To convert metric tons to tons, multiply by 1.1023.
b. UC = uncanistered; DISP = disposable canister; DPC = dual-purpose canister.
c. For purposes of analysis, only the lower-temperature operating mode with aging is considered with the DISP packaging scenario.
d. The 24-year manufacturing period is for all components except drip shields and begins two years prior to emplacement.
e. The 10-year manufacturing period is for drip shields only and occurs at repository closure.

Solid Waste

Table 4-52 lists the solid waste that manufacturing operations would generate. The annual average amount of solid waste would range from 0.57 to 0.88 metric ton (approximately 0.58 to 0.90 ton) per year during either the 24-year or the 10-year manufacturing periods. The primary waste constituents would be steel and components of steel including nickel, manganese, molybdenum, chromium, and copper. These chemicals could be added to existing steel product manufacturing waste streams for treatment and disposal or recycling.

The analysis assumed that depleted uranium to be incorporated in the components would be delivered to the manufacturing facility properly shaped to fit as shielding for a shipping cask. As a result, depleted uranium waste would not be generated or recycled at the representative manufacturing site and would not pose a threat to worker health and safety. Lead used for gamma shielding would be cast between stainless-steel components for the shipping casks. Although the production of a substantial quantity of lead waste under any of the packaging scenarios would be unlikely, such waste would be recycled.

4.1.15.5.6 *Environmental Justice*

The purpose of this environmental justice assessment is to determine if disproportionately high and adverse health or environmental impacts associated with the manufacture of repository components would affect minority or low-income populations, as outlined in Executive Order 12898 and the President's accompanying cover memorandum. Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* directs Federal agencies to identify and address disproportionately high and adverse human health or environmental effects of their programs and activities on minority and low-income populations. A disproportionately high impact would be an impact (or risk of an impact) in a minority or low-income community that exceeded the corresponding impact on the larger community to a meaningful degree. The analysis discussed below is the analysis used in DIRS 101941-USN (1996, Section 4.8), which was adapted to the manufacturing of components for the Yucca Mountain Repository.

The environmental justice assessment considered human health and environmental impacts from the examination of impacts on air quality, waste generation, and health and safety. The assessment used demographic data to provide information on the degree to which minority or low-income populations would be disproportionately affected. The evaluation identified as areas of concern those in which minority or low-income populations could suffer disproportionately high and adverse impacts.

This evaluation used a representative site based on five facilities that manufacture casks or canisters and related hardware for spent nuclear fuel.

To explore potential environmental justice concerns, this assessment examined the composition of populations living within approximately 16 kilometers (10 miles) of the five manufacturing facilities to identify the number of minority and low-income individuals in each area. The percentages of minority and low-income persons comprising the population of the states where the facilities are located were used as a reference. DOE selected this radius because it would capture the most broadly dispersed environmental consequences associated with the manufacturing activities, which would be impacts to air quality. The number of persons in each target group in the defined area was compared to the total population in the area to yield the proportion of minority and low-income persons within approximately 16 kilometers of each facility.

A geographic information system was used to define areas within approximately 16 kilometers (10 miles) of each facility. Linked to 1990 census data, this analytical tool enabled the identification of block groups within 16 kilometers. In cases where the 16-kilometer limit divided block groups, the system calculated the fraction of the total area of each group that was inside the prescribed distance. This fraction provided the basis for estimating the total population in the area as well as the minority and low-income components.

The analysis indicated that in one location the proportion of the minority population in the area associated with the manufacturing facility is higher than the proportion of the minority population in the state. The difference between the percentage of the minority population living inside the 16-kilometer (10-mile) radius and the state is 1.5 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts for the total population from manufacturing activities associated with all the scenarios, so there would be no disproportionately high and adverse impacts to the minority population near this facility.

In addition, the percentage of the total population that consists of low-income families living within about 16 kilometers (10 miles) of a manufacturing facility would exceed that of the associated state in one instance. The difference in this case was 0.9 percent (DIRS 101941-USN 1996, p. 4-18). DOE anticipates very small impacts to individuals and to the total population, and no special circumstances would cause disproportionately high and adverse impacts to the low-income population living near the facility.

The EIS analysis determined that only small human health and environmental impacts would occur from the manufacture of repository components. Disproportionately high and adverse impacts to minority or low-income populations similarly would be unlikely from these activities.

4.2 Short-Term Environmental Impacts from the Implementation of a Retrieval Contingency or Receipt Prior to the Start of Emplacement

4.2.1 IMPACTS FROM RETRIEVAL CONTINGENCY

Section 122 of the Nuclear Waste Policy Act requires DOE to maintain the ability to retrieve emplaced waste for an appropriate period after the start of emplacement. Nuclear Regulatory Commission regulations at 10 CFR 63.111(e) specify a retrieval period of at least 50 years. Because of this requirement, the EIS analyzed the impacts of retrieval. Although DOE does not anticipate retrieval and it is not part of the Proposed Action, DOE would maintain the ability to retrieve the waste for at least 100 years and possibly for as long as 324 years in the event of a decision to retrieve the waste either to protect the public health and safety or the environment or to recover resources from spent nuclear fuel. Some of the impacts that could occur during retrieval have been addressed in the Proposed Action under the lower-temperature operating mode with surface aging. This operating mode would include surface aging of up to two-thirds of the commercial spent nuclear fuel over a 50-year operations period (Chapter 2, Section 2.1.1.2.2). This aging facility could be used to store a portion of any spent nuclear fuel or high-level radioactive waste that would be retrieved.

This EIS evaluates retrieval as a contingency action and describes potential impacts if it were to occur. The analysis in this EIS assumes that under this contingency DOE would retrieve all the waste and would place it on a surface storage pad pending future decisions about its ultimate disposition. Storage of spent nuclear fuel and high-level radioactive waste on the surface would be in compliance with applicable regulations.

4.2.1.1 Retrieval Activities

If there was a decision to retrieve spent nuclear fuel and high-level radioactive waste from the repository, DOE would move the waste packages from the emplacement drifts to the surface. Operations in the subsurface facilities to remove the waste packages would be the reverse of emplacement operations and would use the same types of equipment (see Chapter 2, Section 2.1.2.2).

4.1.7.4.1 *Occupational Impacts*

Industrial Hazards. Table 4-30 lists impacts to workers from normal industrial workplace hazards for the closure phase. No workplace industrial fatalities (0.2 to 0.25) would be expected during closure. The range of impacts is due to the differences in the length of the closure period, because closure activities are similar under all operating modes.

Table 4-30. Impacts to workers from industrial hazards during the closure phase.[a,b]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature
Involved workers		
Total recordable cases	320	340 - 420
Lost work day cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved workers		
Total recordable cases	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers (totals)[c]		
Total recordable cases	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25

a. Values are rounded to two significant figures.
b. Source: Appendix F, Table F-38.
c. Totals might differ from sums of values due to rounding.

Naturally Occurring Hazardous Material. During closure activities there would be potential for dust to be generated (for example, during preparation and emplacement of excavated rock for backfill). The potential for dust generation, especially in the underground environment, would be less than for subsurface excavation during the construction phase and operations period. As necessary, DOE would use engineering controls and worker protection measures such as those discussed in Section 4.1.7.2.1 for the construction phase to control and minimize potential impacts to workers. Potential impacts would be very small.

Radiological Health Impacts. During the closure phase, subsurface workers would be exposed to radon-222 in the drift atmosphere, to external radiation from radionuclides in the drift walls, and to external radiation from the waste packages. Table 4-31 lists radiological impacts to workers for the closure phase. There is low potential for exposure of surface workers, and most of the radiation dose and potential radiological health impacts would be to subsurface workers. The maximally exposed worker would be a subsurface worker. The estimated radiological health impacts to the worker population for the 10 to 17 year closure phase would range from 0.15 to 0.28 latent cancer fatality. The range in impacts is due mainly to the differences in the length of the phase for the range of operating modes. Estimated radiological health impacts to the maximally exposed individual would range from 6.7 to 13 rem, with a corresponding probability of latent cancer fatality ranging from 0.0027 to 0.0052. The principal sources of exposure to subsurface workers would be from inhalation of radon-222 and its decay products.

4.1.7.4.2 *Public Health Impacts*

Naturally Occurring Hazardous Material. Section 4.1.2.4.1 presents estimated annual average concentrations of cristobalite during the closure phase at the land withdrawal boundary, where members of the public could be exposed. There would be no subsurface excavation during the closure phase, so cristobalite concentrations would be less than for earlier phases. Annual average concentrations of about 0.012 to 0.013 microgram per cubic meter were estimated for the operating modes, and health impacts to

Table 4-31. Radiation dose and radiological health impacts to workers during closure phase.[a,b,c]

Worker group and impact category	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Maximally exposed worker[d]		
Dose, rem		
Involved	6.7	7.9 - 13
Noninvolved	0.36	0.40 - 0.61
Probability of latent cancer fatality		
Involved	0.0027	0.0032 - 0.0052
Noninvolved	0.00014	0.00016 - 0.00024
Worker population		
Collective dose (person-rem)		
Involved	430	480 - 740
Noninvolved	16	18 - 28
Total[e]	450	500 - 770
Number of latent cancer fatalities		
Involved	0.17	0.19 - 0.30
Noninvolved	0.0064	0.0072 - 0.011
Total[e]	***0.18***	***0.2 - 0.31***

a. Numbers are rounded to two significant figures.
b. Source: Appendix F, Table F-39.
c. Closure phase would last 10 to 17 years.
d. The maximally exposed individual would be a subsurface worker.
e. Totals might differ from sums of values due to rounding.

the public would be unlikely. Quantities and resultant concentrations of erionite, if present, would be much lower at locations of public exposure. Potential impacts would be very small.

Radiological Health Impacts. Potential radiation-related health impacts to the public from closure activities would result from exposure to radon-222 and its decay products released in the subsurface exhaust ventilation air. Section 4.1.2.4.2 presents estimates of dose to the public for the closure phase. Table 4-32 lists the estimated dose and radiological health impacts.

Table 4-32. Radiation dose and radiological health impacts to public for the closure phase.[a,b,c,d]

Dose and health impact	Operating mode: Entire phase, Higher-temperature	Entire phase, Lower-temperature	Maximum annual, Higher-temperature	Maximum annual, Lower-temperature
Maximally exposed individual[e]				
Dose (millirem)	3	4.3 - 9.4	0.4	0.57 - 0.87
Latent cancer fatality probability	1.5×10^{-6}	$2.2 - 4.7 \times 10^{-6}$	2.0×10^{-7}	$2.8 - 4.3 \times 10^{-7}$
Exposed 80-km population[f]				
Collective dose (person-rem)	57	83 - 180	7.4	10 - 16
Number of latent cancer fatality	0.028	0.041 - 0.090	0.0037	0.0052 - 0.0081

a. Numbers are rounded to two significant figures.
b. Source: Table 4-7.
c. All dose would be from naturally occurring radon-222 and decay products.
d. The closure phase would last from 10 to 17 years.
e. Individual located at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

Potential radiological health impacts would be small. The probability of a latent cancer fatality occurring in the maximally exposed individual would be 0.0000047 or less. The number of latent cancer fatalities estimated to occur in the exposed population would range from 0.028 to 0.090. Differences in potential impacts are due mainly to differences in the length of the closure phase.

4.1.7.5 Total Impacts to Occupational and Public Health and Safety for All Phases

This section presents estimates of the total human health and safety impacts to workers and members of the public from proposed activities at the Yucca Mountain repository. It describes the total impacts from activities during the construction, operation and monitoring, and closure phases to workers from industrial hazards and radiation exposure, and to members of the public from radiation exposure.

Among other operating factors, total project impacts would depend on the duration of the project. The higher-temperature operating mode would last 115 years, while the lower-temperature operating mode would last from 171 to 341 years. These time periods include a 5-year construction phase and variable time periods for the operation and monitoring phase (100 to 324 years) and closure phase (10 to 17 years), as discussed in the previous sections. In general, the highest potential health and safety impacts would occur during the operation and monitoring phase.

4.1.7.5.1 *Total Impacts to Workers from Industrial Hazards for All Phases*

Total impacts to workers from industrial hazards for the entire project are shown in Table 4-33. The estimated number of workplace fatalities would range from 2.0 for the higher-temperature operating mode to 3.3 for the upper end of the lower-temperature operating mode.

Table 4-33. Total impacts to workers from industrial hazards for all phases.[a]

Worker group and impact category	Operating mode	
	Higher-temperature	Lower-temperature[b]
Involved workers		
Total recordable cases	2,200	2,500 - 3,300
Lost work day cases	1,000	1,200 - 1,500
Fatalities	1.5	1.8 - 2.6
Noninvolved workers		
Total recordable cases	460	500 - 720
Lost workday cases	230	250 - 350
Fatalities	0.45	0.48 - 0.68
All workers (totals[c,d])		
Total recordable cases	2,700	3,000 - 4,000
Lost workday cases	1,300	1,500 - 1,900
Fatalities	2.0	2.3 - 3.3

a. Numbers are rounded to two significant figures.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
c. Source: Tables 4-21, 4-24, 4-27, and 4-30.
d. Totals might differ from sums of values due to rounding.

4.1.7.5.2 *Total Radiological Health Impacts to Workers for All Phases*

Total radiation dose and radiological health impacts to workers for the entire project (all phases) are listed in Table 4-34. Dose and impact for the maximally exposed individual worker are listed for a 50-year working lifetime. The collective dose to the worker population and potential radiological health impacts are shown for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode.

Table 4-34. Total radiation dose and radiological health impacts to workers for all phases.[a,b]

Worker group and impact category	Operating mode: Higher-temperature	Lower-temperature
Maximally exposed worker[d]		
Dose, rem		
Involved	18	18 - 30
Noninvolved	1.8	1.8
Probability of latent cancer fatality		
Involved	0.0072	0.0072 - 0.012
Noninvolved	0.00072	0.00072
Worker population		
Collective dose (person-rem)		
Involved	9,700	11,000 - 17,000
Noninvolved	240	280 - 360
Total[e]	**10,000**	**11,000 - 17,000**
Number of latent cancer fatalities		
Involved	3.9	4.4 - 6.8
Noninvolved	0.092	0.11 - 0.14
Total[e]	**4.0**	**4.4 - 6.8**

a. Numbers are rounded to two significant figures.
b. Source: Tables 4-22, 4-25, 4-28, and 4-31 for the construction phase, operations period, monitoring period, and closure phase, respectively.
c. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
d. For a 50-year working lifetime.
e. Totals might differ from sums of values due to rounding.

The maximally exposed worker is a subsurface worker whose 50-year working lifetime would span the 50-year operations period needed for aging of spent nuclear fuel. This worker would be a locomotive operator or brakeman who is involved in the transport and emplacement of the spent nuclear fuel. Receiving an estimated radiation dose of about 30 rem, the probability of incurring a latent cancer fatality would be about 0.012 for this individual.

The total estimated number of latent cancer fatalities that could occur in the repository workforce from the radiation dose received over the entire project would be about 4 for the 115 years of exposure during the higher-temperature operating mode. The number of latent cancer fatalities would range from 4.4 to 6.8, for the 171 to 341 years, respectively, of the lower-temperature operating mode. About 80 percent of the dose and associated risk of latent cancer fatality would occur during the operations period for surface and subsurface workforce. The principal source of exposure would be external radiation from spent nuclear fuel handling in surface facilities and waste package emplacement in the subsurface facility. Inhalation of radon-222 and its decay products by subsurface workers would account for 25 percent of the total worker dose. Ambient radiation exposure to subsurface workers would account for about 10 percent of the total worker dose.

4.1.7.5.3 *Total Radiological Health Impacts to the Public for All Phases*

The estimated radiation dose and radiological health impacts to the public for the entire project—which includes the period prior to final repository closure—are listed in Table 4-35. Dose and the potential radiological impact are listed for the offsite maximally exposed individual, assumed to reside continuously for a 70-year lifetime at the southern boundary of the land withdrawal area. This individual would have a probability of latent cancer fatality of 0.000031 or less from exposure to radionuclides released from the repository during the preclosure period. More than 99.9 percent of the potential health impact would be from naturally occurring radon-222 and its decay products released in exhaust

Table 4-35. Total dose and radiological impacts to the public for all phases.[a,b,c,d]

	Operating mode			
	Higher-temperature	Lower-temperature[e]	Higher-temperature	Lower-temperature[e]
Dose and health impact	Entire project		Maximum annual	
Maximally exposed individual[f]				
Dose (millirem)	31	44 - 62	0.73	1 - 1.3
Latent cancer fatality probability	1.6×10^{-5}	$2.2 - 3.1 \times 10^{-5}$	3.7×10^{-7}	$5.2 - 6.7 \times 10^{-7}$
Exposed 80-km population[g]				
Collective dose (person-rem)	930	1,900 - 3,900	14	20 - 26
Number of latent cancer fatality	0.46	0.97 - 2	0.0071	0.010 - 0.013

a. Numbers are rounded to two significant figures.
b. Source: Table 4-8, Section 4.1.2.5.
c. Greater than 99.9 percent of dose would be from naturally occurring radon-222 and decay products.
d. Project would last from 115 to 341 years.
e. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because these values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
f. Individual located at the southern boundary of the land withdrawal area for a 70-year lifetime including all of the operations period (24 or 50 years) with the remainder during the monitoring period.
g. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).

ventilation air. The highest annual radiation dose would range from 0.73 to 1.3 millirem, less than 1 percent of the annual 200-millirem dose to members of the public in Amargosa Valley from ambient levels of naturally occurring radon-222 and its decay products (Chapter 3, Section 3.1.8.2).

The collective or population dose and associated radiological health impacts are listed in Table 4-35 for the population within 80 kilometers (50 miles) for the entire project duration, ranging from 115 years for the higher-temperature operating mode up to 341 years for the lower-temperature operating mode. An estimated 0.46 latent cancer fatality would occur for the higher-temperature operating mode, and from 0.97 to 2.0 latent cancer fatalities would occur for the lower-temperature operating mode. Statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause (DIRS 153066-Murphy 2000, p. 8). Assuming this rate would remain unchanged for the estimated population (in 2035) of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be expected to die from cancer-related causes. During the time the project was active, the number of cancer deaths unrelated to the project would range from about 30,000 to 89,000 in the general population. Estimated project-related impacts (0.46 to 2 latent cancer fatalities) would be a very small increase (0.007 percent or less) over this baseline. The potential human health impacts of long-term repository performance are discussed in Chapter 5.

4.1.8 ACCIDENT SCENARIO IMPACTS

This section describes the impacts from potential accident scenarios from performance confirmation, construction, operation and monitoring, and closure activities. The analysis is separated into radiological accidents (Section 4.1.8.1) and nonradiological accidents (Section 4.1.8.2). The analysis of radiological accident consequences used the MACCS2 computer code (DIRS 103168-Chanin and Young 1998, all). The receptors would be (1) the *maximally exposed individual,* defined as a hypothetical member of the public at the point on the land withdrawal boundary that would receive the largest dose from the assumed accident scenario, (2) the *involved worker,* a worker who would be handling the spent nuclear fuel or high-level radioactive waste when the accident occurred, (3) the *noninvolved worker*, a worker near the accident but not involved in handling the material, and (4) members of the public who reside within approximately 80 kilometers (50 miles) of the proposed repository. All analysis method details are provided in Appendix H.

The impacts to offsite individuals from repository accidents would be small, with calculated doses of 0.038 rem or less to the maximally exposed offsite individual. Doses to a maximally exposed noninvolved worker would be higher than those to offsite individuals, up to 16 rem. Some of the very unlikely accidents would be expected to severely injure or kill involved workers.

4.1.8.1 Radiological Accidents

The first step in the radiological accident analysis was to examine the initiating events that could lead to facility accidents. These events could be external or internal. External initiators originate outside a facility and affect its ability to confine radioactive material. They include human-caused events such as aircraft crashes, external fires and explosions, and natural phenomena such as seismic disturbances and extreme weather conditions. Internal initiators occur inside a facility and include human errors, equipment failures, or combinations of the two. DOE analyzed initiating events applicable to repository operations to define subsequent sequences of events that could result in releases of radioactive material or radiation exposure. For each event in these accident sequences, the analysis estimated and combined probabilities to produce an estimate of the overall accident probability for the sequence. In addition, the analysis used bounding (plausible upper limit) accident scenarios to represent the impacts from groups of similar accidents. Finally, it evaluated the consequences of the postulated accident scenarios by estimating the potential radiation dose and radiological impacts.

ACCIDENT TYPES

Radiological accidents are unplanned events that could result in exposure of nearby humans to direct radiation or to radioactive material that would be ingested or inhaled.

Nonradiological accidents are unplanned events that could result in exposure of nearby humans to hazardous or toxic materials released to the environment as a result of the accident.

The analysis used accident analyses previously performed by others for repository operation whenever possible to identify potential accidents. DOE reviewed these analyses for their applicability to the repository before using them (see Appendix H). The spectrum of accident scenarios evaluated in the analysis is based on the current conceptual design of the facility. Final facility design details are not available; the final designs could affect both the frequency and consequences of postulated accidents. For areas without final facility design criteria, DOE made assumptions to ensure that the analysis did not underestimate impacts.

The radionuclide *source term* for various accident scenarios could involve several different types of radioactive materials. These would include commercial spent nuclear fuel from both boiling- and pressurized-water commercial reactors (see Appendix A, Section A.2.1), DOE spent nuclear fuel (see Appendix A, Section A.2.2), DOE high-level radioactive waste incorporated in a glass matrix (see Appendix A, Section A.2.3), and weapons-grade plutonium either immobilized in high-level radioactive waste glass matrix or as mixed-oxide fuel (see Appendix A, Section A.2.4). Appendix A contains information on the radionuclide inventories in these materials. The analysis also examined accident scenarios involving the release of low-level waste generated and handled at the repository, primarily in the Waste Treatment Building.

The analysis used the radionuclide inventories from Appendix A for a representative fuel element to estimate the material that could be involved in an accident. It used the MACCS2 computer program, developed under the guidance of the Nuclear Regulatory Commission, to estimate potential radiation doses to exposed individuals (onsite and offsite) and population groups from postulated accidental releases of radionuclides. Appendix H contains additional information on the MACCS2 program and the models and assumptions incorporated in it.

The analysis considered radiological consequences of the postulated accidents for the following individuals and populations:

- *Involved worker.* A facility worker directly involved in activities at the location where the postulated accident could occur

- *Maximally exposed noninvolved worker (collocated worker).* A worker not directly involved with material unloading, transfer, and emplacement activities, assumed to be 100 meters (330 feet) downwind of the facility where the release occurs

- *Maximally exposed offsite individual.* A hypothetical member of the public at the nearest point to the facility at the site boundary. The analysis determined that the land withdrawal boundary location with the highest potential exposure from an accidental release of radioactive material would be either about 8 or 11 kilometers (5 or 7 miles) from the accident location (at the western boundary of the land withdrawal area analyzed). The maximally exposed individual for a single-point release of material is different than those for a continuous release (see Section 4.1.2) because the maximally exposed individual could not be present continuously at the western boundary because this is government-owned land.

- *Offsite population.* Members of the public within 80 kilometers (50 miles) of the repository site (see Chapter 3)

Ten accident scenarios were analyzed in detail. These scenarios bound the consequences of credible accidents at the repository. They include accidents in the Cask/Handling Area, the Canister Transfer System, the Assembly Transfer System, the Disposal Container Handling Area, and the Waste Treatment Building. The scenarios consider drops and collisions involving shipping casks, bare fuel assemblies, low-level radioactive waste drums, and the waste package transporter.

The 10 accident scenarios in Tables 4-36 and 4-37 replace the 16 accident scenarios analyzed in the Draft EIS. The number of scenarios was reduced because several accidents analyzed in the Draft EIS were found to be no longer credible based on design changes, revised system-failure probabilities, and new information on the capability of DOE canisters and transportation casks to withstand drops. Details of these changes are in Appendix H, Section H.2.1.1.

Table 4-36 lists the results of the radiological accident consequence analysis under median, or 50th-percentile meteorological conditions. Table 4-37 lists similar information based on unfavorable meteorological conditions (95th-percentile, or those conditions that would not be exceeded more than 5 percent of the time) that tend to maximize potential radiological impacts. Impacts to the noninvolved worker would result from the inhalation of airborne radionuclides and external radiation from the passing plume. Impacts to the maximally exposed offsite individual and the offsite population would result from these exposure pathways and from long-term external exposure to radionuclides deposited on soil during plume passage, subsequent ingestion of radionuclides in locally grown food, and inhalation of resuspended particulates. The analysis did not consider interdiction by DOE or other government agencies to limit long-term radiation doses because none of these doses would be above the Environmental Protection Agency's Protective Action Guides. Interdiction would be likely to occur if the calculated accident doses exceeded these guides.

Table 4-36. Radiological consequences of repository operations accident scenarios for median (50th-percentile) meteorological conditions.

		Maximally exposed offsite individual[c]		Population		Noninvolved worker		Involved worker	
Accident scenario[a,b]	Frequency (per year)[a]	Dose (rem)	LCFi[d]	Dose (person-rem)	LCFp[d]	Dose (rem)	LCFi	Dose (rem)	LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	8.2×10^{-7}	4.1×10^{-10}	4.9×10^{-4}	2.4×10^{-7}	3.6×10^{-4}	1.4×10^{-7}	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	8.7×10^{-6}	4.4×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	4.5×10^{-3}	1.8×10^{-6}	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	$7.4 \text{ x } 10^{-3}$	6.4×10^{-6}	3.2×10^{-9}	6.0×10^{-4}	3.0×10^{-7}	3.1×10^{-5}	1.2×10^{-8}	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	8.4×10^{-3}	2.6×10^{-5}	1.3×10^{-8}	2.5×10^{-3}	1.2×10^{-6}	1.3×10^{-2}	5.2×10^{-6}	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	8.7×10^{-3}	3.4×10^{-5}	1.8×10^{-8}	3.0×10^{-3}	1.5×10^{-6}	1.8×10^{-2}	7.4×10^{-6}	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	8.7×10^{-3}	2.5×10^{-6}	1.3×10^{-9}	1.5×10^{-3}	7.3×10^{-7}	1.0×10^{-3}	4.1×10^{-7}	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	1.0×10^{-2}	5.0×10^{-6}	0.14	7.3×10^{-5}	3.2	1.3×10^{-3}	(f)	(f)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	1.2×10^{-2}	6.0×10^{-6}	0.63	3.2×10^{-4}	4.9	2.0×10^{-3}	(f)	(f)
9. Earthquake with fire in WTB	2.0×10^{-5}	1.6×10^{-5}	8.0×10^{-9}	8.9×10^{-4}	4.4×10^{-7}	8.2×10^{-4}	3.3×10^{-7}	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	5.7×10^{-10}	2.9×10^{-13}	3.0×10^{-8}	1.4×10^{-11}	2.5×10^{-8}	1.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. Source: Appendix H

b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.

c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accident scenarios except 7. For these accidents, the distance would be 8 kilometers (5 miles).

d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Appendix F, Section F.1.1.5.

e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.

f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The *maximum reasonably foreseeable accident scenario* (earthquake, Table 4-37, number 8) for the 95-percent weather conditions would result in an estimated 0.011 additional latent cancer fatality for the same affected population. The more conservative summation of all foreseeable accidents in Table 4-37 results in less than 0.02 additional latent cancer fatality for the exposed population. Thus, the estimated number of latent cancer fatalities for the offsite individuals from accidents would be very small.

The results described in this section assumed that all commercial spent nuclear fuel would arrive at the repository either uncanistered or in canisters not suitable for disposal. In this base case scenario, all of the fuel would have to be handled as bare fuel assemblies in the Waste Handling Building and placed in disposal containers for disposal, as described above. The base case scenario, which assumes that all fuel would have to be handled as bare fuel assemblies, provides a bounding assessment of accident impacts compared to canistered scenarios. The uncanistered fuel, as indicated in Tables 4-36 and 4-37, represents the more meaningful accident risk because of the additional handling operations required and the higher impacts associated with accidents involving bare assemblies. As a consequence, the base case evaluated in this section provides a bounding assessment of accident impacts in relation to the packaging scenarios.

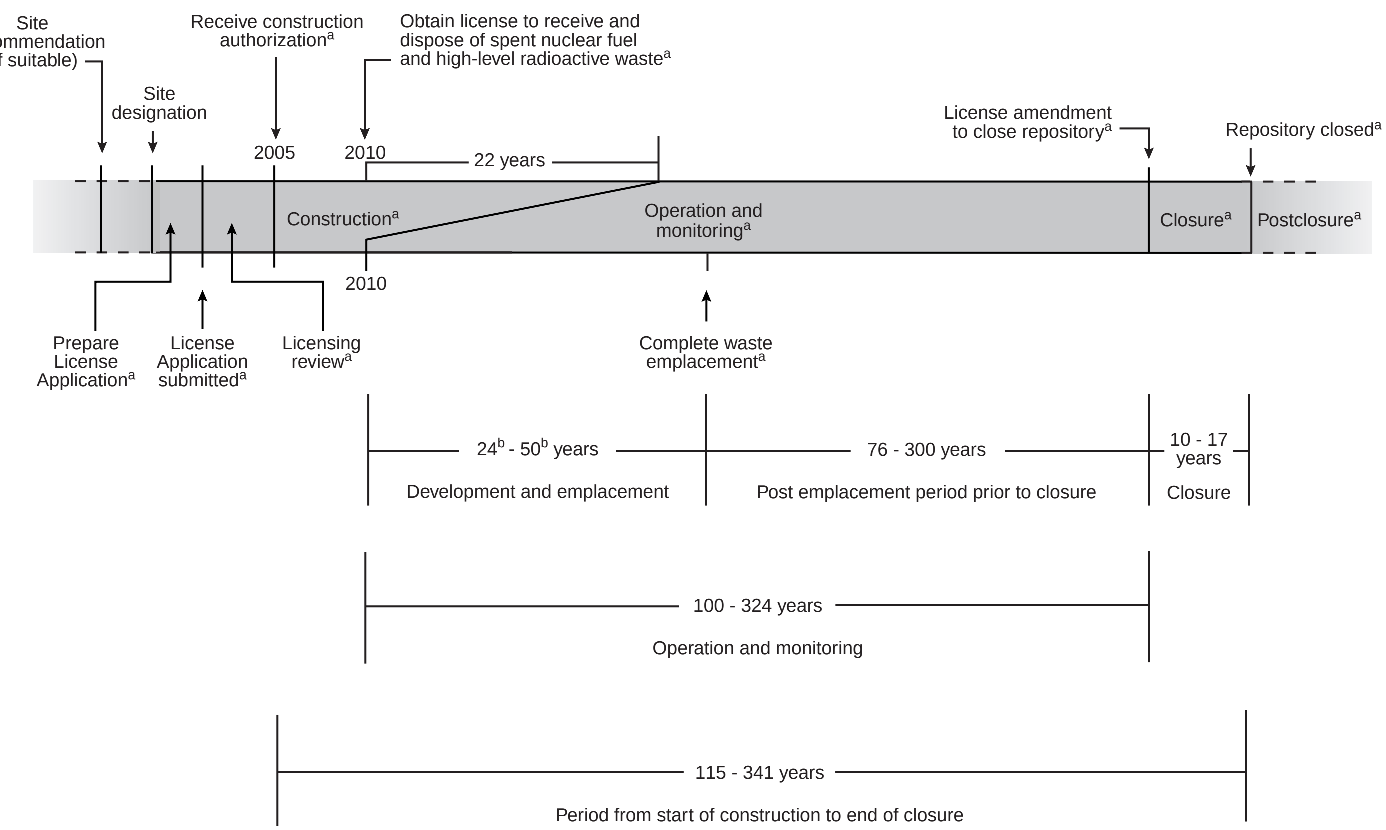
Table 4-37. Radiological consequences of repository operations accident scenarios for unfavorable (95th-percentile) meteorological conditions.

Accident scenario[a,b]	Frequency (per year)[b]	Maximally exposed offsite individual[c] Dose (rem)	Maximally exposed offsite individual[c] LCFi[d]	Population Dose (person-rem)	Population LCFp[d]	Noninvolved worker Dose (rem)	Noninvolved worker LCFi	Involved worker Dose (rem)	Involved worker LCFi
1. Basket drop onto another basket in pool (PWR fuel)	0.04	3.3×10^{-6}	1.7×10^{-9}	4.0×10^{-2}	2.0×10^{-5}	2.0×10^{-3}	8.0×10^{-7}	(e)	(e)
2. Basket drop onto another basket in dryer (PWR fuel)	0.04	3.2×10^{-5}	1.6×10^{-8}	4.7×10^{-2}	2.3×10^{-5}	2.3×10^{-2}	9.2×10^{-6}	(e)	(e)
3. Drop of transfer basket onto another basket in dryer (BWR fuel)	7.4×10^{-3}	2.3×10^{-5}	1.2×10^{-8}	3.0×10^{-2}	1.4×10^{-5}	1.6×10^{-4}	6.4×10^{-8}	(e)	(e)
4. Unsealed DC drop and slapdown in cell (PWR fuel)	8.4×10^{-3}	9.3×10^{-5}	4.7×10^{-8}	0.12	6.2×10^{-5}	7.4×10^{-2}	3.0×10^{-5}	(e)	(e)
5. Unsealed shipping cask drop in CPP (PWR fuel)	8.7×10^{-3}	1.1×10^{-4}	5.5×10^{-8}	0.14	7.2×10^{-5}	0.10	4.1×10^{-5}	(e)	(e)
6. Unsealed shipping cask drop in pool (PWR fuel)	8.7×10^{-3}	1.0×10^{-5}	5.0×10^{-9}	0.12	6.0×10^{-5}	6.0×10^{-3}	2.4×10^{-6}	(e)	(e)
7. Transporter runaway and derailment (PWR fuel)	1.2×10^{-7}	3.8×10^{-2}	1.9×10^{-5}	4.3	2.2×10^{-3}	16	6.4×10^{-3}	(e)	(e)
8. Beyond design basis earthquake in WHB (PWR fuel)	2.0×10^{-5}	3.8×10^{-2}	1.9×10^{-5}	21	1.1×10^{-2}	25	9.8×10^{-3}	(f)	(f)
9. Earthquake with fire in WTB	2.0×10^{-5}	5.4×10^{-5}	2.7×10^{-8}	3.1×10^{-2}	1.5×10^{-5}	6.5×10^{-3}	2.6×10^{-6}	(f)	(f)
10. Low level waste drum rupture in WTB	0.59	1.6×10^{-9}	8.0×10^{-13}	1.1×10^{-6}	5.3×10^{-10}	2.0×10^{-7}	8.0×10^{-11}	8.8×10^{-5}	3.5×10^{-8}

a. Source: Appendix H.
b. DC = Disposal Container, CPP = Cask Preparation Pit, PWR = Pressurized Water Reactor, BWR = Boiling Water Reactor, WHB = Waste Handling Building, WTB = Waste Treatment Building.
c. Assumed to be at the nearest land withdrawal boundary, which would be 11 kilometers (7 miles) for all accidents except 7. For these accidents, the distance would be 8 kilometers (5 miles).
d. LCFi is the estimated likelihood of a latent cancer fatality for an individual who receives the calculated dose. LCFp is the estimated number of cancers in the exposed population from the collective population dose (person-rem). These values were computed based on a conversion of dose in rem to latent cancers as discussed in Section F.1.1.5.
e. For these cases, the involved workers are not expected to be vulnerable to exposure during an accident because operations are done remotely. Thus, involved worker impacts were not evaluated.
f. For these events, involved workers would likely be severely injured or killed by the event; thus, no radiological impacts were evaluated. For the seismic event, as many as 39 people could be injured or killed in the Waste Handling Building, and as many as 36 in the Waste Treatment Building based on staffing projections (DIRS 104718-CRWMS M&O 1998, pp. 17 and 18).

The analysis also evaluated the probability of an aircraft crash onto storage modules which could be used in a surface aging facility. A military aircraft crash onto a storage module was found to be a reasonably foreseeable event; however, the analysis determined that the aircraft would not penetrate the storage module and no release would occur. A crash of a commercial jet airliner into the surface aging facility was also evaluated, even though the probability of such an event is not reasonably foreseeable. The results of the evaluation also indicate no penetration of the storage modules and no release of radiological materials. Details are provided in Appendix H, Section H.2.1.3.

In addition to the reasonably foreseeable accidents summarized in this section, DOE evaluated a hypothetical beyond-credible event (annual probability less than 1 in 10 million) involving an aircraft crash into the repository (see Appendix H, Section H.2.1.5.1). It was determined that an aircraft crash into the Waste Handling Building would result in the maximum estimated consequences. DOE assumed that evacuation of potentially exposed individuals would occur one day after the event, and also that contaminated food and water would be monitored and confiscated if necessary. The dose to the maximally exposed individual was estimated to be 4.5 rem, with a 0.0023 probability of a latent cancer fatality. The dose to the population within 80 kilometers (50 miles) was estimated to be 78 person-rem, with 0.039 latent cancer fatality resulting from this dose.



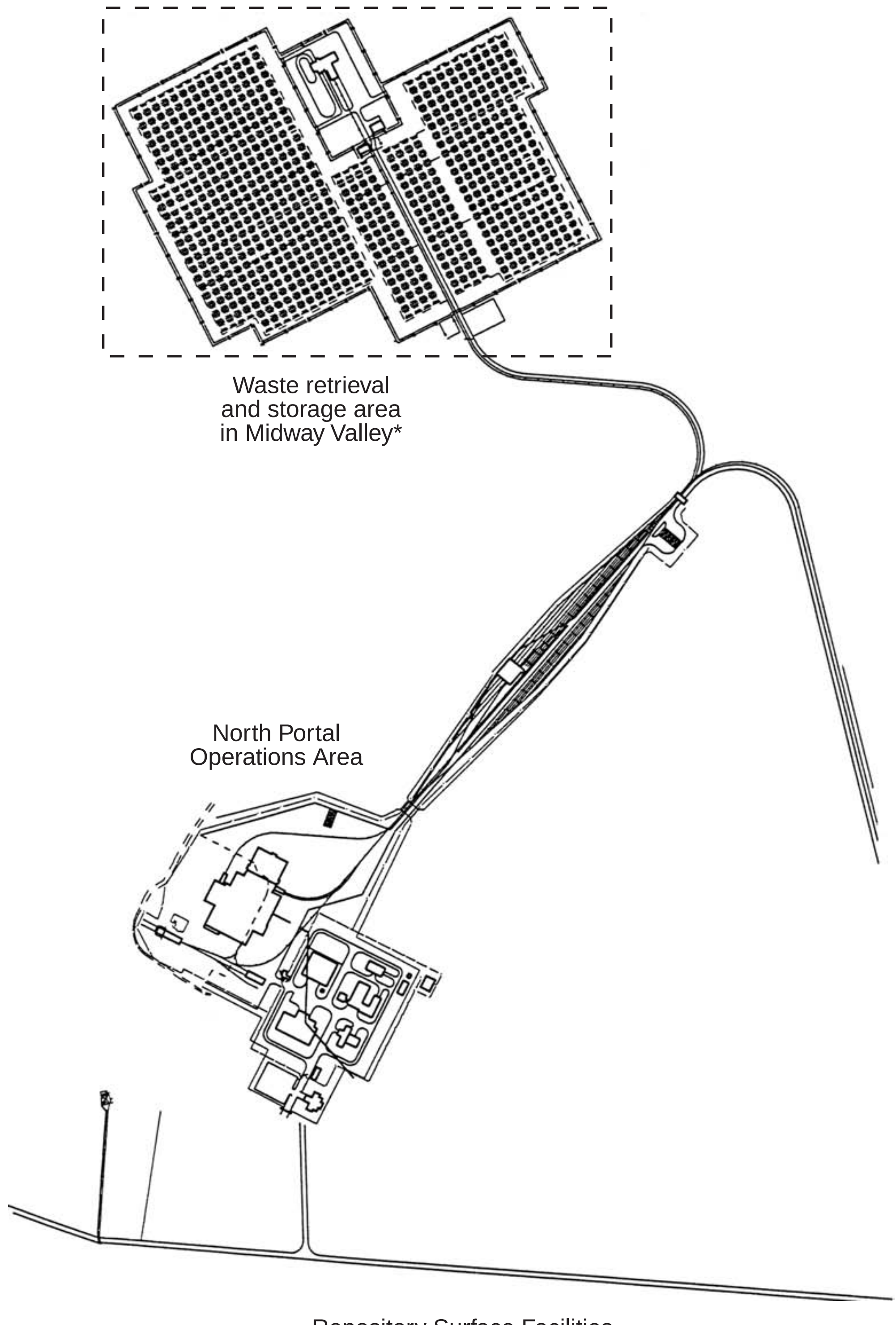
a. If Yucca Mountain is approved.

b. Analysis without aging assumed that waste emplacement would occur over a 24-year period and analysis with aging assumed that waste emplacement with commercial spent nuclear fuel aging would occur over a 50-year period.

Note: See Table 2-2 for range of emplacement, preclosure ventilation, and closure durations.

Sources: Modified from DIRS 104523-CRWMS M&O (1999, Figure 1.5-1, p.1-3).

Figure 4-1. Monitored geologic repository range of milestones used for analysis.



*See Figure 3-12 for more specific location of Midway Valley.

Source: DIRS 104508-CRWMS M&O (1999, Attachment I, Figure I-1).

Figure 4-5. Location of the Waste Retrieval and Storage Area in relation to the North Portal Operations Area.

DOE assumed that the receipt and emplacement of spent nuclear fuel and high-level radioactive waste would begin in 2010 and occur over a 24-year period (70,000 MTHM at approximately 3,000 MTHM per year), unless surface aging was used, in which case there would be a 50-year operations period. The EIS considers the potential for the transport of spent nuclear fuel or high-level radioactive waste to the Yucca Mountain site several years before the waste was actually emplaced in the repository as a contingency action, not part of the Proposed Action. DOE recognizes that regulatory changes would have to occur for the receipt of spent nuclear fuel and high-level radioactive waste before the start of emplacement, and would have to build a facility similar to that described as part of the retrieval contingency (Section 4.2.1.1) for the receipt of these materials pending their emplacement.

Such a facility would consist of a series of concrete pads in the Midway Valley Wash area (the same area described for the retrieval contingency). The facility would be capable of storing as much as 40,000 MTHM of spent nuclear fuel and high-level radioactive waste in concrete storage modules.

The types of impacts resulting from the construction and operation of a Waste Staging Facility would be similar to those from the implementation of a retrieval contingency, described in Section 4.2.1. The impacts would include land disturbance, emission of particulate and gaseous pollutants, and radiation doses from the handling of spent nuclear fuel and high-level radioactive waste. In all cases, potential impacts would be bounded by those presented for the lower-temperature operating mode in Section 4.1.

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Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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5. ENVIRONMENTAL CONSEQUENCES OF LONG-TERM REPOSITORY PERFORMANCE

This chapter describes potential human health impacts from radioactive and nonradioactive materials released to the environment during the first 10,000 years after closure of a repository at Yucca Mountain. The impact calculations assumed that the population in the Yucca Mountain region would remain constant at the number of people projected to live in the region in 2035, as discussed in Chapter 3, Section 3.1.7.1. This chapter also estimates the peak radiation dose during the first 1 million years after closure. Closure of a repository would include the following events, which are analyzed in Chapter 4:

- Sealing of the underground emplacement drifts
- Backfilling and sealing of other underground openings
- Removal of the surface facilities
- Creation of institutional controls, including land records and surface monuments, to identify the location of the repository and discourage human intrusion

In addition, this chapter discusses estimates of potential biological impacts from radiological and chemical groundwater contamination and potential environmental impacts of such contamination and potential biological impacts from the long-term production of heat due to decay of the radioactive materials that would be disposed of in a repository at Yucca Mountain; and potential environmental justice impacts. Other than human impacts, these would be the only potential long-term impacts. There would be no repository activities; no changes in land use, employment of workers, water use or water quality other than from the transport of radionuclides; and no use of energy or other resources, or generation or handling of waste after closure of a repository. Therefore, analysis of impacts to land use, noise, socioeconomics, cultural resources, surface-water resources, aesthetics, utilities, or services after closure is not required. As part of closure activities, the U.S. Department of Energy (DOE, or the Department) would return the land to its original contour and erect appropriate monuments marking the repository, which would result in some minor impacts on aesthetics depending on the exact design of the monuments (currently undetermined). Impacts from closure are discussed in Chapter 4. After the completion of closure, risk of sabotage or intruder access would be highly unlikely. Chapter 4 (Section 4.1.8.3) discusses the potential for sabotage prior to closure. Section 5.7.1 discusses potential impacts from an intruder after closure.

DOE performed the analysis of potential impacts after repository closure for two operating modes—higher-temperature and lower-temperature. For analysis purposes, the same fundamental repository design was used in both modes, but the heat output per unit area of the repository was varied by changing waste package spacing and other operational parameters (see Section 2.1.1.2 in Chapter 2 for details).

The analysis for this EIS considered the following three transport pathways through which spent nuclear fuel, high-level radioactive waste, and hazardous or *carcinogenic* chemicals could reach human populations and cause health consequences:

- Groundwater
- Surface water
- Atmosphere

The principal *exposure pathway*, groundwater, would result from rainwater migrating down through the unsaturated zone into the repository, dissolving some of the material in the repository, and carrying contaminants from the dissolved material downward through the unsaturated zone and on through the groundwater system to locations where human exposure could occur. A surface-water pathway could occur if groundwater reached the surface at a discharge location, so the analysis for this Final EIS considered surface-water consequences along with groundwater consequences. An airborne pathway could result because spent nuclear fuel contains some radionuclides in gaseous form. For example, carbon-14 could migrate to the surface in the form of carbon dioxide gas and mix in the atmosphere.

The analysis for this EIS estimated potential human health impacts from the groundwater transport pathway at three locations in the Yucca Mountain groundwater hydrology region of influence:

- Water wells at the *reasonably maximally exposed individual* (RMEI) location [For this EIS, DOE determined that the RMEI location would be at the southern-most point of the controlled area, as specified in 40 CFR Part 197 (36 degrees, 40 minutes, 13.6661 seconds north latitude). Groundwater modeling indicates that the point at which the predominant groundwater flow crosses the boundary would be about 18 kilometers (11 miles) downgradient from the potential repository. This EIS refers to this location as the "RMEI location."]

- 30 kilometers (19 miles) downgradient from the potential repository.

- The nearest surface-water discharge point, which is about 60 kilometers (37 miles) downgradient from the potential repository.

These consequences are presented in terms of radiological dose and the probability of a resulting latent cancer fatality. A latent cancer fatality is a death resulting from cancer caused by exposure to ionizing radiation or other carcinogens.

DOE assessed the processes by which waste could be released from a repository at Yucca Mountain and transported to the environment. The analysis used computer programs developed to assess the release and movement of radionuclides and hazardous materials in the environment. Some of the programs analyzed the behavior of engineered components such as the waste package, while others analyzed natural processes such as the movement of groundwater. The programs are based on the best available geologic, topographic, and hydrologic data and current knowledge of the behavior of the materials proposed for the system. The analysis used data from the Yucca Mountain site characterization activities, material tests, and expert opinions as input parameters to estimate human health consequences. Many parameters used in the analysis cannot be exactly measured or known; only a range of values can be known. The analysis accounted for this type of uncertainty; thus, the results are ranges of potential health consequences.

WASTE PACKAGE

A *waste package* consists of the waste form and any containers (disposal container, barriers, and other canisters), spacing structure or baskets, shielding integral to the container, packing in the container, and other absorbent materials immediately surrounding an individual disposal container, placed inside the container, or attached to its outer surface. The waste package begins its existence when the outer lid welds are complete and accepted and the welded unit is ready for emplacement in the repository.

The analysis for this Final EIS considered human health impacts during the first 10,000 years after repository closure and the peak dose during the first 1 million years after repository closure. Estimates of potential human health impacts from the *nominal scenario* (undisturbed by volcanic activity or human intrusion) included the effects of such expected processes as corrosion of waste packages, dissolution of waste forms, flow through the saturated and unsaturated zone, seismic events, and changing climate. Additional analyses examined the effects of exploratory drilling, criticality, and volcanic events.

A number of changes have occurred since the issuance of the Draft EIS. Several changes have been made to the repository and waste package designs and many changes have been made to the models used to analyze long-term repository performance. Key design changes important to the long-term performance include changes to the waste package design, changes to how thermal loading of the repository is implemented, and addition of titanium drip shields over the waste packages. Chapter 2, Section 2.1.2; Chapter 4, Section 4.1; Section 5.2; and Appendix I, Section I.2, and the supporting documents referenced therein contain more details on the design changes. In addition, many improvements have been made to the analysis models. These improvements have enhanced the sensitivity of the models to more processes and effects and have refined treatment of uncertainties in some areas. Table 5-1 summarizes the changes. The changes identified in the column titled "S&ER Reference" were addressed in the Supplement to the Draft EIS. The other changes identified in Table 5-1 are addressed in this Final EIS. Further details can also be found in the references cited in Table 5-1 and in Appendix I, Section I.2. The relationship between published Total System Performance Assessment (TSPA) models and both the Draft EIS and this Final EIS are provided in Figure 5-1.

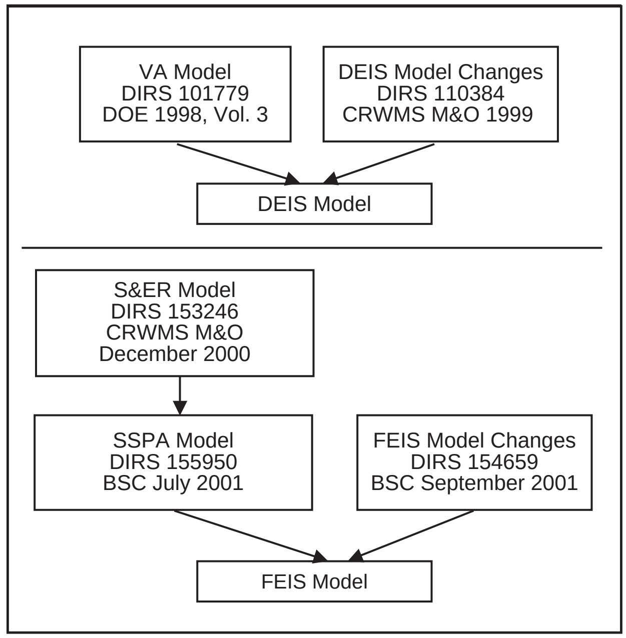

Figure 5-1. Relationship between the published TSPA models and models used for both the Draft EIS and this Final EIS.

5.1 Inventory for Performance Calculations

DOE proposes to dispose of approximately 11,000 to 17,000 waste packages containing as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in a repository at Yucca Mountain. There are several different types of disposal containers for commercial spent nuclear fuel and different container designs for DOE spent nuclear fuel and high-level radioactive waste. The exact number of waste packages would depend on various options in the proposed design. This long-term consequence analysis identified the inventory by the source category of waste material to be disposed of (commercial spent nuclear fuel, DOE spent nuclear fuel, weapons-usable plutonium, and high-level radioactive waste). For purposes of modeling, the inventory for each of the categories was averaged into an appropriate number of packages, each with identical contents. The average of the modeled inventories resulted in a total of nearly 12,000 idealized waste packages (slightly higher than the actual number of waste packages that would be emplaced) in two basic types.

Note that while the simulations were based on the nearly 12,000 packages, there would be no difference in the result if the smaller packages had been used (17,000 package case). This is because the use of smaller packages is merely a way of implementing the lower-temperature operating mode and would contain the same proposed inventory.

5.1.1 INVENTORY OF RADIOACTIVE MATERIALS

There are more than 200 radionuclides in the waste inventory (see Appendix A). The analysis for this Final EIS used a reduced number of radionuclides (26; see Appendix I, Section I.3).

Table 5-1. Changes to the TSPA model since publication of the Draft EIS (page 1 of 2).

Submodel	Change	Estimated effect	S&ER reference[a]	SSPA reference[b]	Model for this Final EIS[c]
Inventory	New inventory abstraction	Neutral	4.2.6.4.1		
	U.S. Navy spent nuclear fuel modeled as commercial spent nuclear fuel rather than as DOE-owned spent nuclear fuel	Neutral			5.2
Unsaturated zone flow	Updated climate model	Neutral	4.2.1.1.1		
	Added interaction of moisture in fractures and rock matrix	Possible reduction in dose	4.2.1.1.4		
	Added perched water models	Neutral	4.2.1.3.1.2		
	Flow through unsaturated zone and, therefore, seepage varies with time	More climate sensitivity, possible increase in dose	4.2.1.3.6		
	Flow-focusing within heterogeneous permeability field; episodic seepage	Possible increase in dose		4.3.1, 4.3.2, 4.3.5	
	Multiscale thermal-hydrologic model, including effects of rock dryout	Possible increase in dose		5.3.1	
	Thermal property sets	Neutral		5.3.1	
	Thermal effects on seepage	Possible increase in dose		4.3.5	
	Coupling between thermal, hydrologic, and chemical effects	Possible increase in dose	4.2.2.1.2		
Waste package and drip shield degradation	Changes to model new package design and addition of drip shield model	Decrease in dose up to 10,000 years	4.2.4.3		
	Improved early package failure model	Decrease in dose up to 10,000 years		7.3.2	
	Experimental corrosion data replacing expert judgment	Decrease in dose up to 10,000 years, increase in peak dose after 10,000 years	4.2.4.3.2		
	General corrosion rate independent of temperature	Increase in dose			5.2
Waste form degradation	Updated cladding degradation model to include mechanical failures and localized corrosion	Increase in dose	4.2.6.3.3		
	Add comprehensive model of colloid formation effects on radionuclide mobilization	Increase in dose	4.2.6.3.8		
	Increased number of radionuclides modeled from 9 to 21	Increase in dose	4.4.1.4		
	Neptunium solubility model incorporating secondary phases	Decrease in dose after 10,000 years	4.2.6.3.7		
Engineered barrier system transport	New comprehensive model for transport of radionuclides from colloid effects	Increase in dose	4.2.7.4.2		
Unsaturated zone transport	New comprehensive model for transport of radionuclides from colloid effects	Increase in dose	4.2.8.4.3		
	Model updated to include radiation connections in the thermal-hydrologic submodel for the lower-temperature operating mode	Neutral			5.2
	Effect of drift shadow zone-advection/ diffusion splitting	Decrease in dose		11.3.1	

Table 5-1. Changes to the TSPA model since publication of the Draft EIS (page 2 of 2).

Submodel	Change	Estimated effect	S&ER reference[a]	SSPA reference[b]	Model for this Final EIS[c]
Saturated zone flow and transport	Colloid-facilitated transport in two modes: as an irreversible attachment of radionuclides to colloids, originating from waste, and as an equilibrium attachment of radionuclides to colloids	Increase in dose	4.2.9.4		
	Three-dimensional transport model	Neutral	4.2.9.4		
	Plume capture method for well concentrations (total radionuclides dissolved in water usage)	Possible decrease in dose	4.2.9.4		
	Change in length of saturated zone from 20 kilometers (12 miles) downgradient from the potential repository for MEI[d] in Draft EIS to RMEI[e] location determined by DOE to be approximately 18 kilometers, or 11 miles, downgradient from the potential repository	Possible increase in dose			5.2
Biosphere	Change in basis for biosphere dose conversion factors from MEI in the Draft EIS to the average member of the critical group defined in draft 10 CFR Part 63	Neutral	4.2.10.1		
	Change in basis for biosphere dose conversion factors from the average member of the critical group (10 CFR Part 63) in the S&ER and SSPA to the RMEI defined in EPA regulation 40 CFR Part 197	Slight decrease			5.2
	Consideration of groundwater protection standards	New impact measure	4.4.2		
	Change in water volume used for evaluation of groundwater protection standards from sampled model dilution volume to the representative volume (3,000 acre-feet per year) defined in EPA regulation 40 CFR Part 197	Decrease in new impact measure			5.2

a. Section numbers in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (DIRS 153849-DOE 2001, all).
b. Section numbers in the SSPA-*Supplemental Science and Performance Analysis* (DIRS 155950-BSC 2001, all).
c. Section numbers in DIRS 157307-BSC (2001, Enclosure 1).
d. MEI = maximally exposed individual.
e. RMEI = reasonably maximally exposed individual.

The number of radionuclides to be analyzed was determined by a screening analysis. The screening analysis identified those radionuclides that would collectively contribute at least 95 percent of the dose to a person living in the vicinity of Yucca Mountain. The list of radionuclides resulting from the screening process forms the basis for the analyses discussed in this chapter. Appendix I, Section I.3, contains more details of this screening analysis.

The total inventory was abstracted into two types of idealized waste packages: a codisposal package with high-level radioactive waste in a glass matrix and DOE spent nuclear fuel, and a commercial spent nuclear fuel package. Table 5-2 lists the abstracted inventory for the idealized waste packages. For

IDEALIZED WASTE PACKAGES

The number of waste packages used in the performance assessment simulations do not exactly match the number of actual waste packages projected for the Proposed Action.

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and codisposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages, the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis of long-term performance. The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.

Table 5-2. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package.[a,b]

Nuclide	Commercial spent nuclear fuel waste packages[c]	Codisposal waste packages[d]	
		DOE spent nuclear fuel	High-level radioactive waste
Actinium-227	0.00000309	0.000113	0.000467
Americium-241	10,900	117	65.7
Americium-243	1,290	1.49	0.399
Carbon-14	1.37	0.0496	0.00643
Cesium-137	5,340	112	451
Iodine-129	1,800	25.1	48
Neptunium-237	4,740	47.9	72.3
Protactinium-231	0.00987	0.325	0.796
Lead-210	0	0.000000014	0.000000114
Plutonium-238	1,510	6.33	93.3
Plutonium-239	43,800	2,300	3,890
Plutonium-240	20,900	489	381
Plutonium-242	5,410	11.1	7.77
Radium-226	0	0.00000187	0.0000167
Radium-228	0	0.00000698	0.00000319
Strontium-90	2,240	55.4	288
Technetium-99	7,680	115	729
Thorium-229	0	0.0266	0.00408
Thorium-230	0.184	0.0106	0.00782
Thorium-232	0	14,900	7,310
Uranium-232	0.0101	0.147	0.000823
Uranium-233	0.07	214	11.1
Uranium-234	1,830	57.2	47.2
Uranium-235	62,800	8,310	1,700
Uranium-236	39,200	853	39.8
Uranium-238	7,920,000	509,000	261,000

a. Source: DIRS 154841-BSC (2001, Table 36, p. 38).
b. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the potential repository would be different.
c. There are 7,860 idealized commercial spent nuclear fuel waste packages.
d. There are 3,910 idealized codisposal waste packages.

analysis purposes, naval spent nuclear fuel is conservatively modeled as commercial spent nuclear fuel (DIRS 152059-BSC 2001, all; DIRS 153849-DOE 2001, Section 4.2.6.3.9, p. 4-257).

5.1.2 INVENTORY OF CHEMICALLY TOXIC MATERIAL

DOE is not proposing to dispose of chemically toxic waste in the potential repository. However, the degradation of engineered materials that would be used in repository construction and engineered barrier systems would result in corrosion products that contain chemically toxic materials.

A screening analysis reported in Appendix I (Section I.6.1) showed that the only chemical materials of concern for the 10,000-year analysis period were those released as the external wall of the waste package and the waste package support pallet materials corroded. The chemicals of concern would be chromium, nickel, molybdenum, and vanadium. The exposed surface areas that would corrode include Alloy-22 surfaces (drip shield rails, outer layer of waste packages, and portions of the emplacement pallets) and stainless steel 316NG surfaces (portions of the emplacement pallets).

The total quantities of materials would be 86,000,000 kilograms (190,000,000 pounds) of Alloy-22 (DIRS 150558-CRWMS M&O 2000, p. 6-6) containing 22.5 percent chromium, 14.5 percent molybdenum, 57.2 percent nickel, 0.35 percent vanadium (DIRS 104328-ASTM 1998, all) and 140,000,000 kilograms (310,000,000 pounds) of stainless steel, (DIRS 150558-CRWMS M&O 2000, p. 6-6) which is 17 percent chromium, 12 percent nickel and 2.5 percent molybdenum. A large percentage of the stainless steel would be inside the waste package (as an inner sleeve) and, therefore, much of this material would not be exposed until the Alloy-22 had corroded away.

5.2 System Overview

Radioactive materials in the repository would be placed at least 200 meters (660 feet) beneath the surface (DIRS 154554-BSC 2001, pp. 28-29). In physical form, the emplaced materials would be almost entirely in the form of solids with a very small fraction of the total radioactive inventory in the form of trapped gases (see Section 5.5). With the exception of a small amount of radioactive gas in the fuel rods, the primary means for the radioactive and chemically toxic materials to contact the *biosphere* would be along groundwater pathways. The materials could pose a threat to humans if the following sequence of events occurred:

- The waste packages and their contents were exposed to water
- Radionuclides or chemically toxic materials in the package materials or wastes became dissolved or mobilized in the water
- The radionuclides or chemically toxic materials were transported in water to an aquifer, and the water carrying radionuclides or chemically toxic materials was withdrawn from the aquifer through a well or at a surface-water discharge point and used directly by humans for drinking or in the human food chain (such as through irrigation or watering livestock).

Thus, the access to, and flow of, contaminated water are the most important considerations in determining potential health hazards.

analysis purposes, naval spent nuclear fuel is conservatively modeled as commercial spent nuclear fuel (DIRS 152059-BSC 2001, all; DIRS 153849-DOE 2001, Section 4.2.6.3.9, p. 4-257).

5.1.2 INVENTORY OF CHEMICALLY TOXIC MATERIAL

DOE is not proposing to dispose of chemically toxic waste in the potential repository. However, the degradation of engineered materials that would be used in repository construction and engineered barrier systems would result in corrosion products that contain chemically toxic materials.

A screening analysis reported in Appendix I (Section I.6.1) showed that the only chemical materials of concern for the 10,000-year analysis period were those released as the external wall of the waste package and the waste package support pallet materials corroded. The chemicals of concern would be chromium, nickel, molybdenum, and vanadium. The exposed surface areas that would corrode include Alloy-22 surfaces (drip shield rails, outer layer of waste packages, and portions of the emplacement pallets) and stainless steel 316NG surfaces (portions of the emplacement pallets).

The total quantities of materials would be 86,000,000 kilograms (190,000,000 pounds) of Alloy-22 (DIRS 150558-CRWMS M&O 2000, p. 6-6) containing 22.5 percent chromium, 14.5 percent molybdenum, 57.2 percent nickel, 0.35 percent vanadium (DIRS 104328-ASTM 1998, all) and 140,000,000 kilograms (310,000,000 pounds) of stainless steel, (DIRS 150558-CRWMS M&O 2000, p. 6-6) which is 17 percent chromium, 12 percent nickel and 2.5 percent molybdenum. A large percentage of the stainless steel would be inside the waste package (as an inner sleeve) and, therefore, much of this material would not be exposed until the Alloy-22 had corroded away.

5.2 System Overview

Radioactive materials in the repository would be placed at least 200 meters (660 feet) beneath the surface (DIRS 154554-BSC 2001, pp. 28-29). In physical form, the emplaced materials would be almost entirely in the form of solids with a very small fraction of the total radioactive inventory in the form of trapped gases (see Section 5.5). With the exception of a small amount of radioactive gas in the fuel rods, the primary means for the radioactive and chemically toxic materials to contact the *biosphere* would be along groundwater pathways. The materials could pose a threat to humans if the following sequence of events occurred:

- The waste packages and their contents were exposed to water
- Radionuclides or chemically toxic materials in the package materials or wastes became dissolved or mobilized in the water
- The radionuclides or chemically toxic materials were transported in water to an aquifer, and the water carrying radionuclides or chemically toxic materials was withdrawn from the aquifer through a well or at a surface-water discharge point and used directly by humans for drinking or in the human food chain (such as through irrigation or watering livestock).

Thus, the access to, and flow of, contaminated water are the most important considerations in determining potential health hazards.

5.2.1 COMPONENTS OF THE NATURAL SYSTEM

Figure 5-2 is a simplified schematic of a repository at Yucca Mountain. It shows the principal features of the natural system that could affect the long-term performance of the repository. Yucca Mountain is in a semiarid desert environment where the current average annual precipitation over the unsaturated zone flow and transport model area is 170 millimeters (7 inches), varying by specific location (DIRS 153849-DOE 2001, p. 4-38). The water table is an average of about 600 meters (2,000 feet) below the surface of the mountain. The proposed repository would be in unsaturated rock approximately midway between the desert environment and the water table.

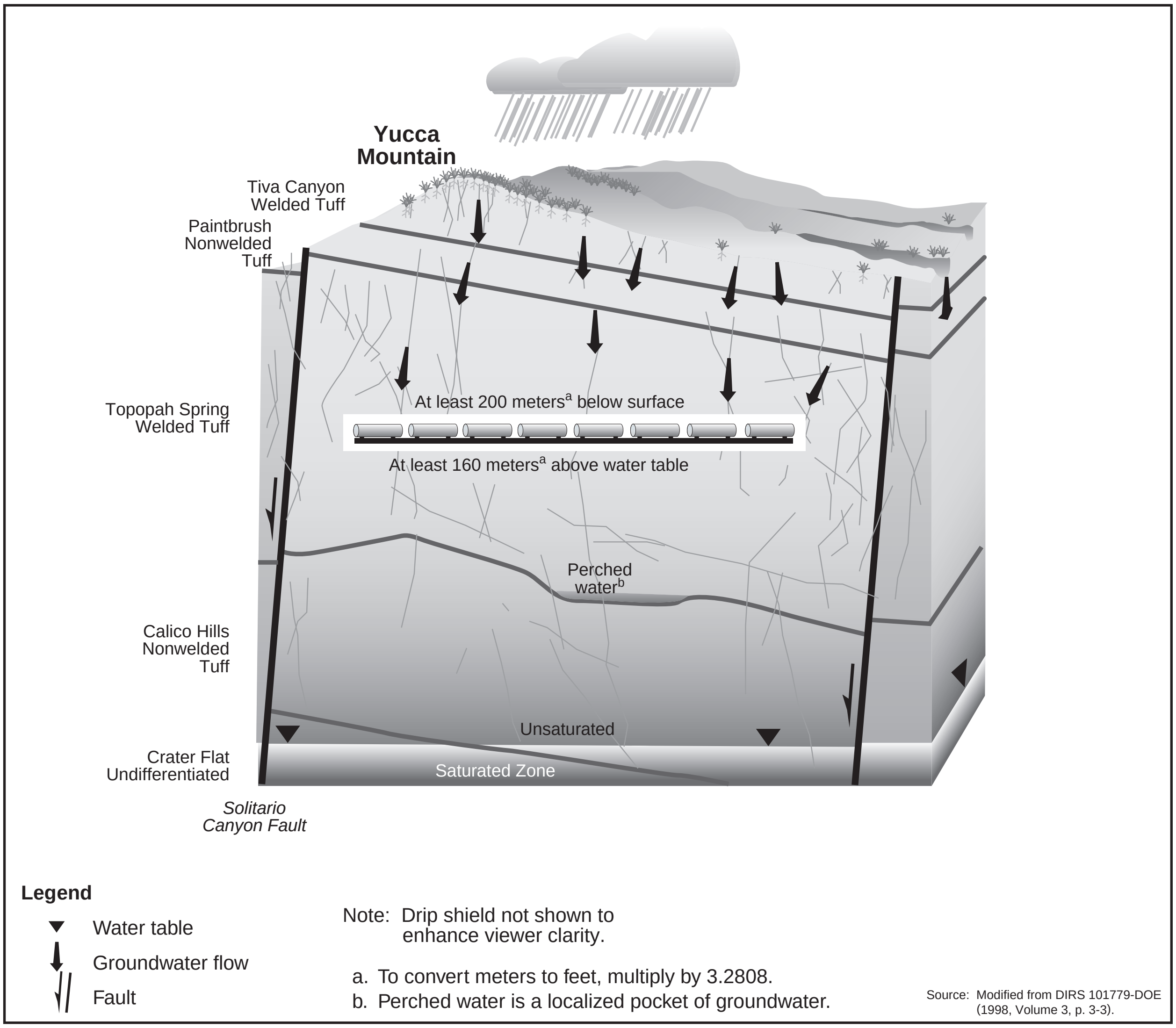

Figure 5-2. Components of the natural system.

The water table is the boundary between the unsaturated zone above and the saturated zone below. In the subsurface region above the water table, the rock contains water but the water does not fill all the open spaces in the rock. Because the open spaces are only partially filled, this region is called the unsaturated zone. Water in the unsaturated zone tends to move generally downward in response to capillary action and gravity. In contrast, water fills all the open spaces in the rock below the water table, so this region is called the saturated zone. Water in the saturated zone tends to flow laterally from higher to lower pressures. Both zones contain several different rock types, as shown in Figure 5-2. The layers of major rock types in the unsaturated zone at the Yucca Mountain site are the Tiva Canyon welded, Paintbrush nonwelded, Topopah Spring welded, Calico Hills nonwelded, and Crater Flat undifferentiated tuffs. Figure 5-2 shows two of the faults at the proposed site-the Ghost Dance fault that occurs within the repository block and the Solitario Canyon Fault that forms the western boundary of the repository block. Faults are slip zones where rock units have become displaced either vertically, laterally, or diagonally, resulting in the rock layers being discontinuous. These slip zones tend to form a thin plane in which there is more open space that acts as a channel for water. Some faults tend to fill with broken rock formed as they slip, so they take on a very different flow property from that of the surrounding rock. The proposed repository would be in the Topopah Spring welded tuff in the unsaturated zone, at least 200 meters (660 feet) below the surface and at least 160 meters (530 feet) above the water table (DIRS 154554-BSC 2001, pp. 28-29).

HYDROGEOLOGIC TERMS

Saturated zone: The area below the water table where all spaces (fractures and rock pores) are completely filled with water.

Unsaturated zone: The area between the surface and the water table where only some of the spaces (fractures and rock pores) are filled with water.

Matrix: The solid, but porous, portion of the rock.

When it rains in the Yucca Mountain vicinity, most of the water runs off and a very limited amount infiltrates the rock on the surface of the mountain. Some of the water that remains on the surface or infiltrates the rock evaporates back into the atmosphere (directly or through plant uptake and evapotranspiration). The very small amount of water that infiltrates the rock and does not evaporate percolates down through the mountain to the saturated zone (DIRS 155950-BSC 2001, Section 3.3.2.1, p. 3-17). Water that flowed through the unsaturated zone into the proposed repository could dissolve some of the waste material, if there was a breach in the package containment, and could carry it through the groundwater system to the accessible environment, where exposure to humans could occur.

5.2.2 COMPONENTS OF THE WASTE PACKAGE AND DRIP SHIELD

The waste package would consist of two concentric cylindrical containers sealed with welded lids in which DOE would place the waste forms. The inner cylinder would be stainless steel (316NG). The outer cylinder would be a corrosion-resistant nickel-based alloy (Alloy-22). Alloy-22 would protect the underlying structural material (stainless steel) from corrosion, while the structural material would support the thinner, corrosion-resistant material. The current design calls for emplacement of a titanium drip shield over the waste packages just prior to repository closure. With the drip shield in place, the Alloy-22 outer cylinder would be the second corrosion barrier protecting the waste from contact with water. The use of two distinctly different corrosion-resistant materials would reduce the probability that a single environmental condition could cause the failure of both materials. Before the double-walled waste package was sealed, helium would be added as a fill gas. The helium would prevent corrosion of the waste form and help transfer heat from the waste form itself to the inner wall of the waste package. Moving heat away from the waste form would be one important means of controlling waste form temperatures. This would help preserve the integrity of the metal cladding on the fuel rods, thus extending the life of an already-existing barrier that protects the waste from water.

5.2.3 VISUALIZATION OF THE REPOSITORY SYSTEM FOR ANALYSIS OF LONG-TERM PERFORMANCE

In general, the repository system was modeled as a series of processes linked together, one after the other, spatially from top to bottom in the mountain. From a computer-modeling standpoint, it is important to break the system into smaller portions that relate to the way information is collected. In reality, an operating repository system would be completely interconnected, and virtually no process would be independent of other processes. However, the complexity of such a system demands some idealization of the system for an analysis to be performed.

The first step in the visualization of the system is the development of a listing of all the possible features, events, and processes that could apply to the behavior of the system. An example of a *feature* is the existence of a fault, an example of an *event* is a seismic event (earthquake), and an example of a *process* is the gradual degradation of the waste package wall by general corrosion. The list is then screened using various types of analyses to determine what features, events, and processes should be included in the modeling. The chosen features, events, and processes are then assembled into scenarios, which are descriptions of how features, events, and processes link together to result in a certain outcome (see Appendix I, Section I.2.1, for further detail).

The elements of the TSPA model are organized into the following categories, which are generally related to various parts of the system:

- Unsaturated zone flow
- Engineered barrier system environments
- Waste package and drip shield degradation
- Waste form degradation
- Engineered barrier transport
- Unsaturated zone transport
- Saturated zone flow and transport
- Biosphere

The individual models associated with these elements are discussed in Appendix I, Sections I.2.2 through I.2.9.

In addition, the following special scenarios are also discussed in Appendix I, Sections I.2.10 through I.2.13:

- Volcanism
- Human intrusion
- Nuclear criticality
- Atmospheric radiological transport

During the development of the TSPA model, DOE often had to make assumptions. The main reason for assumptions was to account for situations where there was limited data. With additional data, it may be possible to present a more "realistic" representation, usually as a statistical distribution. If data are limited, it is necessary to make assumptions and use associated conservative data values. The Nuclear Regulatory Commission and Environmental Protection Agency rulemaking processes acknowledged that uncertainty about physical processes acting over the large space and time scales of interest will remain, even after many years of site characterization. The long-term analysis does not seek an exact prediction but rather seeks to establish a representative projection. The list of assumptions is too large to include here. Table 5-3 is an index to a series of tables that describe in detail the assumptions in the model and associated key attributes. The detailed information is in the Total System Performance Assessment-Site Recommendation document (DIRS 153246-CRWMS M&O 2000, pp. F-2 to F-9).

Table 5-3. Cross-reference to key assumptions and associated attributes in the TSPA model.[a]

Category	TSPA-Site Recommendation table[b]
Unsaturated zone flow and transport	F-1
Near-field environment	F-2
Engineered barrier system—chemical environment and radionuclide transport	F-3
Drip shield/waste package	F-4
Inventory component	F-5
In-package chemistry component	F-6
Commercial spent nuclear fuel degradation component	F-7
Defense spent nuclear fuel degradation component	F-8
High-level radioactive waste degradation component	F-9
Dissolved concentration component	F-10
Colloidal concentration component	F-11
Saturated zone flow and transport	F-12
Biosphere	F-13
Disruptive events	F-14

a. Some assumptions were modified in the *Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all). See Table 1-1 of that document for a summary of areas where assumptions were modified or revised.
b. See DIRS 153246-CRWMS M&O (2000, pp. F-2 to F-9).

5.2.4 UNCERTAINTY

As with any impact estimate, there is a level of uncertainty associated with the forecast, especially when estimating impacts over thousands of years. Uncertainty can be defined as the measure of confidence in the forecast related to determining how a system will operate or respond. The amount of uncertainty associated with an impact estimate is a reflection of several factors, including the following four factors:

- An understanding of the components of a system (such as human and societal, hydrogeologic, or engineered) and how those components interact. The greater the number of components, the more complex the system, the lesser the capability to measure or understand how the system or components produce a greater potential for uncertainty. Similarly, fewer studies or more assumptions produce greater potential for uncertainty.

- The time scale over which estimates are made. Longer time scales for forecasts produce greater potential for uncertainty.

- The available computation and modeling tools. More general computation tools or more assumptions produce greater potential for uncertainty.

- The stability and uniformity (or variability) of the components and system being evaluated. Less stability and uniformity (that is, greater variability) produces a greater potential for uncertainty.

DOE recognizes that uncertainties exist from the onset of an analysis; however, forecasts are valuable in the decisionmaking process because they provide insight based on the best information and scientific judgments available. The following section discusses uncertainties in the context of possible effects on the impact estimates reported in this chapter. The discussion is divided to address:

- Uncertainty associated with societal changes and climate
- Uncertainty associated with currently unavailable data
- Uncertainty associated with models and model parameters

5.2.4.1 Uncertainty Associated with Societal Changes, Climate, and Other Long-Term Phenomena

General guidance on predicting the evolution of society has been provided by the National Academy of Sciences. In its report, *Technical Bases for Yucca Mountain Standards* (DIRS 100018-National Research Council 1995, all), the Committee on Technical Bases for Yucca Mountain Standards concluded that there is no scientific basis for predicting future human behavior. The study recommends policy decisions that specify the use of default (or reference) scenarios to incorporate future human behaviors in compliance assessment calculations. The analysis in this chapter generally follows the recommended approach, using as defaults societal conditions as they exist today and the assumption that populations would remain at their present locations. These assumptions, while appropriate for estimating impacts for comparison with other proposed actions, are not realistic because it is likely that populations will move and change in size. Therefore, DOE has chosen to project population size for 2035 (see Chapter 3, Section 3.1.7.1). If populations were to move closer to or increase in size in the Yucca Mountain groundwater region of influence, the radiation dose and resultant impacts could increase. DOE does not have the means to predict such changes quantitatively with great accuracy; therefore, the analysis does not attempt to quantify the resultant effects on overall impacts. In addition, the analysis does not address the potential benefits from future human activities including improved technology for removing radioactive materials from drinking water or the environment or medical advances such as cures for cancer.

Estimates of future climatic conditions are based on what is known about the past, with consideration given to climate impacts caused by human activities. Calcite in Devils Hole, a fissure in the ground approximately 40 kilometers (25 miles) southeast of Yucca Mountain, provides the best-dated record of climate changes over the past 500,000 years. The record shows continual variation, often with very rapid jumps, between cold glacial climates (for the Great Basin, these are called pluvial periods) and warm interglacial climates similar to the present. Fluctuations average 100,000 years in length (DIRS 153038-CRWMS M&O 2000, Section 6.4.1). The past climate cycles were idealized into a regular cycle of pulses, which were repeated throughout the period of the forecast. This method inherently assumes that the future will repeat the past. However, while current understanding of the causes of climate change allows some confidence in this approach, a considerable amount of conservatism was built into the models to account for possible climate uncertainties. For example, a large range of water fluxes was used to reflect the wide rainfall variations that could occur over thousands and hundreds of thousands of years (DIRS 155950-BSC 2001, Section 3.3.2.6). The analysis assumed that the current climate is the driest it will ever be at Yucca Mountain.

5.2.4.2 Uncertainty Associated with Currently Unavailable Data

Some uncertainties for input parameters or models result from gaps in available data. Such gaps may be due to the status of research (with further data expected later) or conditions that limit gathering of data (such as the need to conduct tests over impractical long periods of time or the necessity to not overly disturb the emplacement site). Uncertainty associated with currently unavailable data is a subset of parameter and model uncertainty that is discussed further in Section 5.2.4.3.

As further discussed in Section 5.2.4.3, the use of parameter distributions and studies of alternative models can provide understanding of how the lack of data affects the range of the impact results. Furthermore, sensitivity studies (see Section 5.2.4.3.4) can also provide insight into the importance of particular parameters. The sensitivity studies sometimes identify data with a small contribution to the results, thereby mitigating concerns arising from their unavailability.

The fact that some data are currently unavailable does not necessarily preclude providing adequate assessment of long-term impacts. When the Draft EIS and the Supplement to the Draft EIS were prepared there was sufficient information to provide an adequate analysis of the long-term performance impacts.

However, additional data have been generated since the publication of those documents. These data have helped improve characterization of the range of impacts in this Final EIS over those reported in the Draft EIS. Some examples of the additional data and their uses are the following:

- Concentrations of chemical components in the rock such as chloride, bromide, and sulfate are being measured, and the results will aid in identifying fast paths for water flow. Ongoing analyses of the isotopic ages of fracture-lining minerals provide preferential information on the history of water movement. These studies show how and when water has moved through the unsaturated zone and reveal characteristics of the water, such as the chemical composition and temperature. This information has been factored into modeling of the unsaturated zone (DIRS 155950-BSC 2001, Section 3.3.2)

- The effects of heating on water seepage into emplacement drifts were investigated in a drift-scale thermal test and by laboratory experiments that support models for predicting the effects of coupled processes over much longer periods (DIRS 155950-BSC 2001, Section 3.3.3)

- Accelerated corrosion testing of Alloy-22 has allowed more definitive quantification of corrosion rates used in improvements in the waste package degradation model (DIRS 155950-BSC 2001, Section 7.2.2)

5.2.4.3 Uncertainty Associated with Models and Model Parameters

The long-term performance model used to assess the impacts from groundwater migration includes a large number of submodels and requires a large amount of input data. The model must account for important features of the system, likely events, and processes that would contribute to the release and migration of materials. Because of the long periods being simulated, the complexity and variability of a natural system, and several other factors, the performance modeling must deal with a large degree of uncertainty. This section discusses the nature of the uncertainties and how they were accounted for in this EIS and their implication to interpretation of impact results. The *Supplemental Science and Performance Analysis* (DIRS 155950-BSC 2001, all) contains further details concerning this subject.

5.2.4.3.1 *Variability Versus Uncertainty*

A variable feature, event, or process is one that changes over space or with time. Examples include the porosity of the rock mass, the temperature in the repository, and the geochemical environment in the repository drifts. If all information was available, such parameters would be best expressed as known mathematical functions of space and time. In contrast, uncertainty relates to a lack of knowledge regarding a feature, event, or process-one whose properties or future outcome cannot be predicted. Four types of uncertainty are typically considered: value uncertainty, *conceptual model* uncertainty, numerical model uncertainty, and uncertainty regarding future events. The treatment of a feature, event, or process as purely variable or purely uncertain can lead to different modeling results.

Uncertainty and variability are sometimes related. The exact nature of the variability in a natural system cannot be known because all parts of the system cannot be observed. For example, DOE cannot dig up all the rock in Yucca Mountain and determine that the positioning of the rock layers is exactly as suggested by core sample data. Therefore, there is uncertainty about the properties of the rock at specific locations in the mountain because properties change with distance and it is not known how much they change at any given location. If the variability can be appropriately quantified or measured, a model usually can be developed to include this variability. If the variability cannot be physically quantified or estimated, it should be treated as uncertainty (lack of knowledge). However, the ability to model some types of spatial variability can be limited not only by lack of data but also by the capacity of a computer to complete calculations (for example, if one simulation took weeks or months to complete). In these instances, variability must be simplified in such a way as to be conservative (that is, the simulation would overestimate the impact).

Two basic tools were used in the analysis to deal with uncertainty and variability: alternative conceptual models and probability theory. Alternative conceptual models were used to handle uncertainty in the understanding of a key physical-chemical process controlling system behavior. Probability theory was used to understand the impacts of uncertainty in specific model parameters (that is, would results change if the parameter value was different). In particular, uncertain processes often required different conceptual models. For example, different conceptual models of how water in fractures communicates with water in the smaller pores or the matrix of the rock in the unsaturated zone lead to different flow and transport models. Sometimes conceptual models are not mutually exclusive (for example, both matrix and fracture flow might occur), and sometimes they do not exhaustively cover all possibilities (apparently matrix and fracture flow do cover all possibilities). These examples indicate that the use of alternative conceptual models, while often necessary to characterize some types of uncertainty, is not always as exact as desired.

A process of weighting alternative conceptual models (as described below) was used in the long-term consequence analysis to account for uncertainties in conceptual models. The Monte Carlo sampling technique was used for handling uncertainty in specific model parameters and for alternative conceptual models that were weighted beforehand with specific probabilities. The method involves random sampling of ranges of likely values, or *distributions*, for all uncertain input parameters. Distributions describe the probability of a particular value in the range. A common type of distribution is the familiar "bell-shaped" curve, also known as the *normal distribution*. Parameters in the consequence analysis are described by many different types of distributions appropriate for how the values and their probabilities are understood. Numerous realizations of the repository system behavior were calculated, each based on one set of samples of all the inputs. Each total system realization had an associated probability so that there is some perspective on the likelihood of that set of circumstances occurring. The Monte Carlo method yields a range for any chosen performance measure (for example, peak annual individual dose in a given period at a given location) along with a probability for each value in the range. In other words, it gives an estimate of repository performance and determines the possible errors based on the estimate. In this chapter, the impact estimates are expressed as the mean of all the realizations and the 95th-percentile value (that is, the value for which 95 percent of the results were smaller).

CALCULATING THE MEAN AND 95TH-PERCENTILE RESULTS

DOE calculated a mean and 95th-percentile dose history by selecting the mean and 95th-percentile value at each time step in the simulation. Thus, the mean dose history consisted of the average of all 300 realizations of dose rate at each time step, and the 95th-percentile dose history consisted of the 95th-percentile at each time step. The EIS analysis determined the peak value from these dose histories, and the EIS discusses the "peak of the mean dose history" and the "peak of the 95th-percentile dose history."

5.2.4.3.2 *Weighting of Alternative Conceptual Models*

In some cases, modeling alternatives form a continuum, and sampling from the continuum of assumptions fits naturally in the Monte Carlo framework of sampling from probability distributions. In other cases, the assumptions or models are discrete choices. In particular, some processes are so highly uncertain that there are not enough data to justify developing continuous probability distributions over the postulated ranges of behavior. In such cases, a high degree of sampling is unwarranted, and an analysis often models two or three cases that are assumed to encompass the likely behavior.

There were two possible approaches to incorporating discrete alternative models in the performance analysis: weighting all models into one comprehensive Monte Carlo simulation (lumping), or keeping the discrete models separate and performing multiple Monte Carlo simulations for each discrete model (splitting). The main results in Section 5.4 were developed using the splitting approach because they were based on a limited range of uncertainty. Based on expert judgment (and to some extent the finite time and resources that could be applied to the analysis effort), the analysis used a best estimate of the more likely ranges of model behavior and parameter ranges. Some alternative models were not included in the analysis, and some parameter ranges of the included models were narrowed. Because of this narrowed range of models and parameters, the results are conditional, meaning that they depend on certain models and parameters being held constant or having their variance restricted. One such condition is the specific design of the repository and the waste packages in the design evaluated in this EIS. Another important condition is that the cladding on the spent nuclear fuel can be depended on as a barrier. Other conditional results were used to characterize the effect of certain assumptions. For example, splitting was done to consider such events as human intrusion (Section 5.7.1), igneous activity (Section 5.7.2), and criticality (Section 5.8). The consequences of these types of events are not part of results given in Section 5.4; rather they are reported as added impacts with certain probabilities of occurrence.

5.2.4.3.3 *Uncertainty and the Proposed Action*

The analysis for the Proposed Action encompassed many of the underlying uncertainties. It included some of all four types of uncertainty: value or parameter uncertainty, conceptual model uncertainty, numerical model uncertainty, and future-event uncertainty. Therefore, the results represent a "lumping" approach. Uncertainty not lumped into the modeling, which produced the central results in Section 5.4, was addressed discretely in alternative models, alternative features, and alternative events such as human intrusion. These alternatives were "split" from the nominal results, and their effects on performance are described separately.

5.2.4.3.4 *Uncertainty and Sensitivity*

In addition to accounting for the uncertainty, characteristics of the engineered and natural systems (such as the unsaturated and saturated zones of the groundwater system) that would have the most influence on repository performance also need to be understood. This information helps define uncertainty in the context of what would most influence the results. This concept is called sensitivity analysis. A number of methods are used to explain the results and quantify sensitivities. Total system performance is a function of sensitivity (if a parameter is varied, how much do the performance measures change) and uncertainty (how much variation of a parameter is reasonable). For example, the long-term performance results could be very sensitive to a certain parameter, but the value for the parameter is exactly known. In the uncertainty analysis techniques described below, that parameter would not be regarded as important. However, many parameters in the analyses do have an associated uncertainty and do become highly important to performance. On the other hand, the level of their ranking can depend on the width of the assigned uncertainty range.

Many of the important uncertain parameters were examined in alternative models. The alternative models either expand the range of the parameters beyond the expected range of uncertainty or change the weighting of the parameter distribution. For example, this type of analysis was performed for alternative models of seepage (DIRS 101779-DOE 1998, Volume 3, pp. 5-1 to 5-9) and cladding degradation (DIRS 101779-DOE 1998, Volume 3, pp. 5-32 to 5-35). An example of alternative model studies for volcanic hazards is discussed in DIRS 155950-BSC (2001, Section 14.3.1, p. 14-6).

System performance could be sensitive to repository design options, but models and parameters for these various options do not have an assigned uncertainty. Therefore, although they can be important, they do not show up as key parameters based on an uncertainty analysis. The determination of the parameters or components that are most important depends on the particular performance measure being used. This point was demonstrated in the 1993 TSPA (DIRS 100111-CRWMS M&O 1994, all; DIRS 100191-Wilson et al. 1994, all) and the Total System Performance Assessment-1995 (DIRS 100198-CRWMS M&O 1995, all). For example, these two analyses showed that the important parameters would be different for 10,000-year peak doses than for 1-million-year peak doses.

There are several techniques for analyzing uncertainties, including the use of qualitative scatter plots where the results (for example, annual individual dose) are plotted against the input parameters and visually inspected for trends. In addition, performance measures can be plotted against various subsystem outputs or surrogate performance measures (for example, waste package lifetime) to determine if that subsystem or performance surrogate would be important to performance. There are several formal mathematical techniques for analyzing the sets of realizations from a Monte Carlo analysis to extract information about the effects of parameters. Such an analysis determined the principal factors affecting the performance of the repository design.

5.2.4.3.5 *Uncertainty Analysis for the TSPA-Site Recommendation*

The Science and Engineering Report (DIRS 153849-DOE 2001, all) provides the results of a comprehensive quantitative analysis of the possible future behavior of a Yucca Mountain repository. The analysis, documented in the *Total System Performance Assessment for the Site Recommendation* (DIRS 153246-CRWMS M&O 2000, all), combined the results of detailed conceptual and numerical models of each of the individual and coupled processes in a single *probabilistic* model that can be used to assess how a repository might perform over long periods. The TSPA-Site Recommendation was a next-generation analysis after the TSPA-Viability Assessment, which DOE used for analysis of long-term performance in the Draft EIS. The Site Recommendation analysis was the result of design changes to the proposed repository and advancement in knowledge from ongoing research activities.

Despite the extensive scientific studies described in the Science and Engineering Report, DOE has always recognized that uncertainties will remain in any assessment of the performance of a repository over thousands of years, as discussed in that report (DIRS 153849-DOE 2001, Sections 1.5, 4.1, and 4.4). These uncertainties are attributable to a variety of causes, ranging from uncertainty regarding the fundamental processes that could affect radionuclide migration to uncertainty related to the design and operation of the repository. For this reason, one part of the DOE approach to dealing with uncertainty relies on multiple lines of evidence that can contribute to the understanding of the performance of the potential repository. Another part of the DOE approach is a commitment to continued testing, monitoring, and analysis beyond the possible recommendation of the site.

The TSPA-Site Recommendation model incorporated a number of uncertainties. These were uncertainties for which a realistic distribution of parameters is not identified, but rather a very conservative bounding value or bounding range was chosen. Additional studies have investigated effects of unquantified uncertainties and sensitivities in the TSPA model by better quantification of uncertainties and the affected processes. This research is documented in the Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all). (See Appendix I, Section I.2 for more detailed discussion of the evolution of the TSPA model and application to this EIS.) A summary of areas in which the Supplemental Science and Performance Analysis model benefited from these additional uncertainty studies is provided below. The Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all) contains full details of the studies.

Unquantified Uncertainty Analysis

Part of the work described in the Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all) included analysis of unquantified uncertainties. Table 5-4 summarizes the elements of the model that DOE studied and indicates whether or not revised model elements were included in the Supplemental Science and Performance Analysis model. The Supplemental Science and Performance Analysis model, with additional modifications, was used for the long-term performance analysis for this

Table 5-4. Analysis of unquantified uncertainties and resulting TSPA model modifications[a] (page 1 of 2).

Process model (section of S&ER[b])	Topic of unquantified uncertainty analysis	Section of SSPA[c] Volume 1	In Supplemental TSPA[d] model
Seepage into emplacement drifts (4.2.1)	Flow- focusing in heterogeneous permeability field; episodic seepage	4.3.1, 4.3.2, 4.3.5	Yes
	Effects on rock bolts and drift degradation on seepage	4.3.3, 4.3.4	
Coupled effects on seepage (4.2.2)	Thermal effects on seepage	4.3.5	Yes
	Thermal-hydrologic-chemical effects on seepage	4.3.6	
Water diversion performance of engineered barrier system (4.2.3)	Multiscale thermal-hydrologic model, including effects of rock dryout	5.3.1	Yes
	Thermal property sets	5.3.1	Yes
	Effect of in-drift convection on temperature, humidity, invert saturations, and evaporation rates	5.3.2	
	Composition of liquid and gas entering drift	6.3.1	Yes
	Evolution of in-drift chemical environment	6.3.3	Yes
In-drift moisture distribution (4.2.5)	Environment on surface of drip shields and waste packages	5.3.2, 7.3.1	
	Condensation under drip shields	8.3.2	
	Evaporation of seepage	8.3.1, 5.3.2	Yes
	Effect of breached drip shields or waste package on seepage	8.3.3	Yes
	Waste package release flow geometry (flow- through, bathtub)	8.3.4	
Drip shield degradation and performance (4.2.4)	Local chemical environment on surface of drip shields (including magnesium, lead) and potential for initiating localized corrosion	7.3.1	
Waste package degradation and performance (4.2.4)	Local chemical environment on surface of waste packages (including magnesium, lead) and potential for initiating localized corrosion	7.3.1	
	Aging and phase stability effects on Alloy-22	7.3.2	Yes
	Uncertainty in weld stress state following mitigation	7.3.3	Yes
	Weld defects	7.3.3	Yes
	Early failure due to improper heat treatment	7.3.6	Yes
	General corrosion rate of Alloy-22: temperature dependency[e]	7.3.5	Yes
	General corrosion rate of Alloy-22: uncertainty/ variability partition	7.3.5	Yes
	Long- term stability of passive films on Alloy-22	7.3.4	
	Stress threshold for initiation of stress corrosion cracking	7.3.3	Yes
	Distribution of crack growth exponent repassivation slope	7.3.7	Yes
In-package environments (4.2.6)	Effect of HLW[f] glass degradation rate and steel degradation rate on in-package chemistry	9.3.1	Yes
Cladding degradation and performance (4.2.6)	Effect of initial perforations, creep rupture, stress corrosion cracking, localized corrosion, seismic failure, rock overburden failure, and unzipping velocity on cladding degradation	9.3.3	Yes
Defense HLW degradation and performance (4.2.6)	HLW glass degradation rates	9.3.1	
Dissolved radionuclide concentrations (4.2.6)	Solubility of neptunium, thorium, plutonium, and technetium	9.3.2	Yes
Colloid-associated radionuclide concentrations (4.2.6)	Colloid mass concentrations	9.3.4	
Engineered barrier system (invert) degradation and transport (4.2.6, 4.2.7)	Diffusion inside waste package	10.3.1	Yes
	Transport pathway from inside waste package to invert	10.3.2	
	Sorption inside waste package	10.3.4	Yes
	Sorption in invert	10.3.4	Yes
	Diffusion through invert	10.3.3	Yes
	Colloid stability in invert	10.3.5	
	Microbial transport of colloids	10.3.6	
Unsaturated zone radionuclide transport (advective pathways; retardation; dispersion; dilution) (4.2.8)	Effect of drift shadow zone-advection/diffusion splitting	11.3.1	Yes
	Effect of drift shadow zone – concentration boundary condition on engineered barrier system release rates	11.3.1	
	Effect of matrix diffusion	11.3.2, 11.3.3	
Saturated zone radionuclide flow and transport (4.2.9)	Groundwater specific discharge	12.3.1	
	Effective diffusion coefficient in volcanic tuffs	12.3.2	
	Flowing interval (fracture) porosity	12.3.2	
	Effective porosity in alluvium	12.3.2	
	Correlation of effective diffusion coefficient with matrix porosity	12.3.2	
	Bulk density of alluvium	12.3.2	Yes
	Retardation for radionuclides irreversibly sorbed on colloids in alluvium	12.3.2	
	Sorption coefficient in alluvium for iodine, technetium	12.3.2	Yes
	Sorption coefficient in alluvium for neptunium, uranium	12.3.2	
	Sorption coefficient for neptunium in volcanic tuffs	12.3.2	
	Effective longitudinal dispersivity	12.3.2	

Table 5-4. Analysis of unquantified uncertainties and resulting TSPA model modifications.[a] (page 2 of 2).

Process model (section of S&ER[b])	Topic of unquantified uncertainty analysis	Section of SSPA[c] Volume 1	In Supplemental TSPA[d] model
Biosphere (4.2.10)[g]	Individual of interest	13.3.1	
	Comparison of dose assessment methods	13.3.2	
	Radionuclide removal from soil by leaching	13.3.3	
	Uncertainties not captured by GENII-S model	13.3.4	
	Influence of climate change on groundwater usage and biosphere dose conversion factors	13.3.5, 13.3.7	

a. Adapted from DIRS 155950-BSC (2001, Table 1-1, pp. 1T-1 to 1T-6).
b. S&ER - Science and Engineering Report (DIRS 153849 - DOE 2001, all).
c. SSPA - Supplemental Science and Performance Analysis (DIRS 155950-BSC 2001, all).
d. TSPA -Total System Performance Assessment.
e. The temperature dependent corrosion model was not used for this EIS (see Appendix I, Section I.4); the model used for this EIS yields a more conservative result.
f. HLW = high-level radioactive waste.
g. DOE used revised biosphere dose conversion factors for this EIS to conform to the Environmental Protection Agency standard, 40 CFR Part 197.

Final EIS (see Appendix I, Sections I.2 and I.4). The first column of Table 5-4 lists the major process models and a reference to the appropriate section in the Science and Engineering Report (DIRS 153849-DOE 2001, all). The second column lists the individual model elements analyzed in the unquantified uncertainties report. The third column lists sections of Volume 1 of the Supplemental Science and Performance Analysis report (DIRS 155950-BSC 2001, all) that contain additional details on the analysis. The analyses included sensitivity studies or other analysis methods to determine how significant the uncertainty might be. If warranted and possible, changes were made to the Supplemental Science and Performance Analysis model to better characterize the uncertainties; this is noted in the fourth column.

5.2.4.3.6 *Key Parameters and Uncertainty*

DOE performed an analysis to determine which parameters contributed most to the uncertainties in the long-term performance results for the nominal scenario reported in Section 5.4. Such important parameters will be the greatest contributors to variations in calculated impacts because of the high sensitivity of the results to the parameter or high uncertainty in the parameter. In any case, the range of values in the distribution for these parameters exerts the strongest influence on the uncertainty of the results.

Two types of analysis were used: stepwise linear rank regression and classification tree [in which parameters were classified in terms of the separation of outcomes into “high”-dose (top 10th-percentile) and “low”-dose (bottom 10th-percentile) categories] (DIRS 155934-Mishra 2001, all; DIRS 155936-Mon 2001, all).

Regression Analysis

Regression analysis is a tool for quantifying the strength of input-output relationships in the TSPA model. To this end, a stepwise linear rank regression model is fitted between individual dose at a given time (or some other performance measure) and all randomly sampled input variables. Parameters are ranked on the basis of how much their exclusion would degrade the explanatory power of the regression model. The importance ranking measure used for this purpose is the uncertainty importance factor, which is defined as the loss in explanatory power divided by the coefficient of determination of the regression model. The uncertainty importance factor quantifies the proportion of the total spread (variance) in total dose explained by the regression model that can be attributed to the variable of interest.

Classification Tree Analysis

Classification tree analysis, a subset of classification and regression tree analysis, is a method for determining variables or interactions of variables that drive output into particular categories. Classification and regression tree analyses can be used to generate decision rules that determine whether a particular realization would produce "high" or "low" dose depending on the values of the most important variables. Unlike regression analysis, which is based on the total range of model outcomes, classification tree analysis focuses on extreme values of model results and tries to relate them to specific ranges of values for the important variables.

Results

For different time frames in the analysis, different parameters emerge as important to the overall variability of the results (DIRS 155934-Mishra 2001, all and DIRS 155936-Mon 2001, all). Table 5-5 lists the results of the analysis.

Table 5-5. Top-ranking uncertainty importance parameters.[a]

Time after closure	Two most important parameters
125,000 years	General humid air corrosion rate of Alloy-22 outer lid
	General humid air corrosion rate of Alloy-22 inner lid
250,000 years	General humid air corrosion rate of Alloy-22 outer lid
	General humid air corrosion rate of Alloy-22 inner lid
500,000 years	Episodic factor
	General humid air corrosion rate of Alloy-22 outer lid
1,000,000 years	Episodic factor
	Infiltration scenario

a. Sources: DIRS 155934-Mishra (2001, all) and DIRS 155936-Mon (2001, all).

A description of the important parameters identified in Table 5-5 follows:

- *General Humid Air Corrosion Rates of Alloy-22, Inner and Outer Lids –* When the drip shields are intact and no water is dripping on the waste package, the corrosion rate of Alloy-22 is governed by the humid air corrosion rates of the inner lid and the outer lid. The waste package closure end has three lids: an innermost stainless-steel lid, an inner Alloy-22 lid, and an outer Alloy-22 lid. These two corrosion rate parameters govern how the respective Alloy-22 lids degrade when not exposed to dripping water.

- *Episodic Factor –* The conceptual model governing episodic infiltration represents fractures comprised of randomly distributed "pinch-point" and "storage" apertures. Pinch-point apertures act as capillary barriers to the infiltration of water, which accumulates in a volume above the pinch-point dictated by the storage aperture. The water continues to accumulate in the storage aperture until the hydraulic head above the pinch-point aperture exceeds the associated capillary rise height. Once this threshold is reached, the water begins to flow downward under the force of gravity at a rate dictated by the permeability of the aperture. Water continues to flow through the aperture until the accumulated water is completely drained. This behavior leads to an episodic infiltration of water through fractured rock that occurs randomly in space and time. The distribution of a factor that is randomly sampled governs this episodic flow in the numerical model.

- *Infiltration Scenario –* For each of the six *climate states* (see Appendix I, Section I.2.2) there are three possible infiltration rates (low, medium, and high). The particular climate state and infiltration rate is the infiltration scenario. Therefore, this variable is a function of the infiltration rate.

The parameters in Table 5-5 that most affect the total uncertainty in the TSPA model are factors that would govern the degradation of the waste package for the first 250,000 years following repository closure. After 250,000 years, most waste packages would have failed and other factors become important. Even at 500,000 years after repository closure, waste package degradation is still important. At later times the important parameters would be related to factors that influenced the flow of water in the drifts, especially infiltration and episodic flow.

5.3 Locations for Impact Estimates

Yucca Mountain is in the transition area between the Mojave Desert and the Great Basin. This is a semiarid region with linear mountain ranges and intervening valleys, with rainfall averaging between about 100 and 250 millimeters (4 and 10 inches) a year, sparse vegetation, and a small population. Although there is low infiltration of water through the mountain and no people currently live in the land withdrawal area, radioactive and chemically toxic materials released from the repository could affect persons living closer to the proposed repository in the distant future. This section describes the regions where possible human health impacts could occur.

Figure 5-3 is a map with arrows showing the general direction of groundwater movement from Yucca Mountain. Shading indicates major areas of groundwater discharge through a combination of springs and evapotranspiration by plants. The general path of water that infiltrates through Yucca Mountain is south toward Amargosa Valley, into and through the area around Death Valley Junction in the lower Amargosa Desert. Natural discharge of groundwater from beneath Yucca Mountain probably occurs farther south at Franklin Lake Playa (DIRS 100376-Czarnecki 1990, pp. 1 to 12), and spring discharge in Death Valley is a possibility (DIRS 100131-D'Agnese et al. 1997, pp. 64 and 69).

Although groundwater from the Yucca Mountain vicinity flows under and to the west of Ash Meadows in the volcanic tuff or alluvial aquifers, the surface discharge areas at Ash Meadows and Devils Hole (see map in Figure 5-3 for locations) are fed from the carbonate aquifer. While these two aquifers are connected at some locations, the carbonate aquifer has a hydraulic head that is higher than that of the volcanic or alluvial aquifers. Because of this pressure difference, water from the volcanic aquifer does not flow into the carbonate aquifer; rather, the reverse occurs. Therefore, contamination from Yucca Mountain is not likely to mix with the carbonate waters and discharge to the surface at Ash Meadows or Devils Hole (DIRS 104983-CRWMS M&O 1999, all) under current conditions. This pressure difference could change under future climate conditions.

Because, under expected conditions, there would be no contamination of this discharge water, there would be no human health impacts. Furthermore, there would be no consequences to the endangered Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*) or Devils Hole pupfish (*Cyprinodon diabolis*) at those locations.

Figure 3-25 in Chapter 3 shows the projected population of 76,000 residents within 80 kilometers (50 miles) of Yucca Mountain in 2035. This map provides the information used to estimate population doses from radionuclides released to the atmosphere from the repository. The atmospheric analysis in Section 5.5 used the 80-kilometer (50-mile) population distribution described in Section 3.1.8.

In the Draft EIS, impacts were evaluated at 5-kilometer (3-mile), 20-kilometer (12-mile), and 30-kilometer (19-mile) distances from the repository as well as at the groundwater discharge point. The EPA regulation, 40 CFR 197.12, establishes a controlled area around the repository that must not extend farther south than 36 degrees, 40 minutes, 13.6661 north latitude, in the predominant direction of groundwater flow. For this EIS, DOE assumed the controlled area boundary to be the farthest point south. The predominant groundwater flow crosses this boundary approximately 18 kilometers (11 miles) from the repository. Therefore, the 5-kilometer (3-mile) distance would be inside the controlled area, would no longer be part of the accessible environment, and DOE did not evaluate impacts at this distance.

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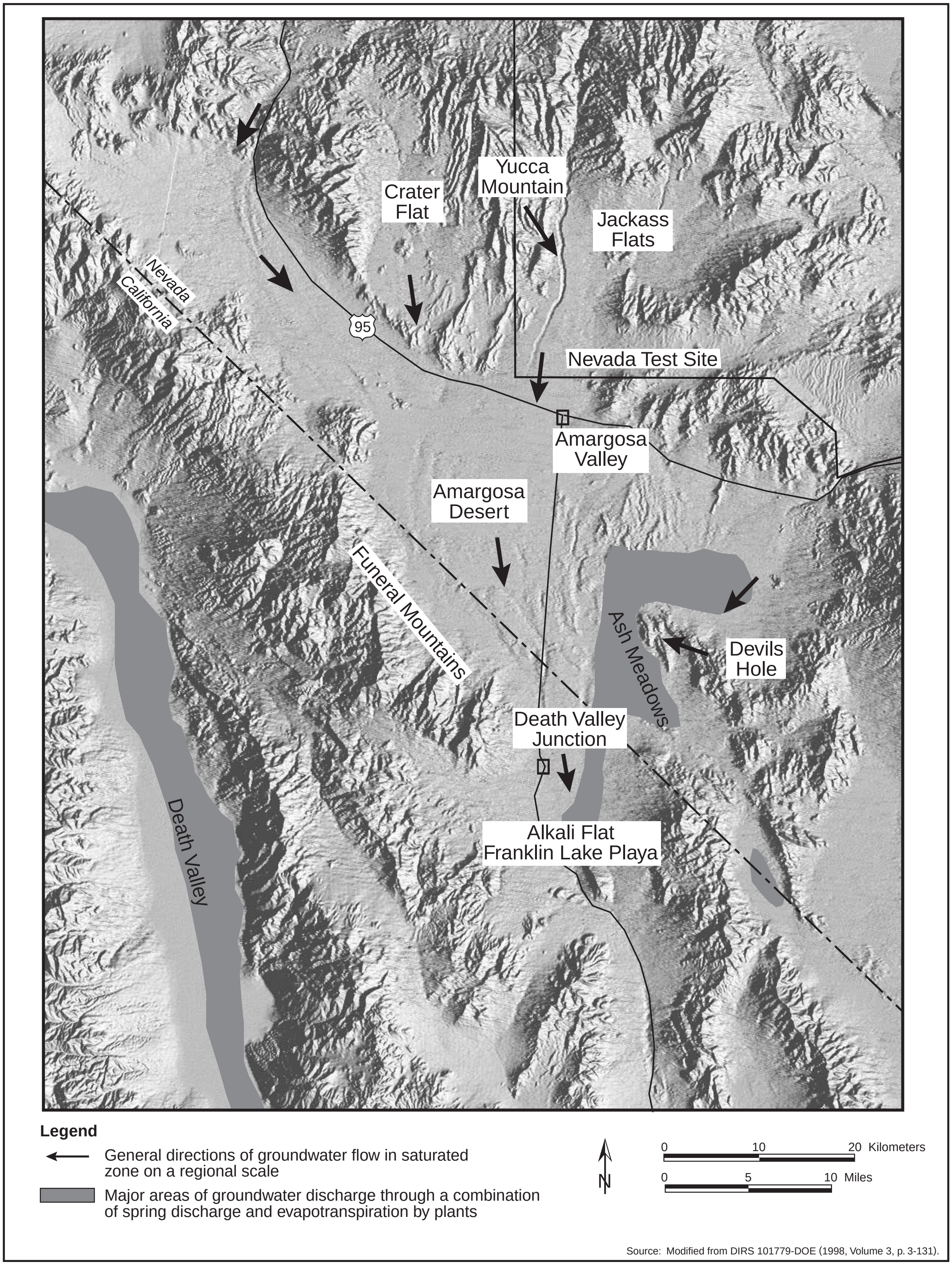

Figure 5-3. Map of the saturated groundwater flow system.

5.4 Waterborne Radiological Consequences

The following sections report the annual committed effective dose equivalent, expressed in millirem, to individuals living at three locations south of Yucca Mountain. These individuals are assumed to use contaminated groundwater and have lifestyle characteristics of the RMEI defined in 40 CFR 197.21. The RMEI is exposed to the high end of the range of potential dose distribution for the exposed population, called "reasonable maximum exposure" conditions. RMEI is a hypothetical person who meets the following criteria:

> **POPULATION DOSE AND FUTURE POPULATION SIZE**
>
> *Population dose* is a summation of the doses received by individuals in an exposed population (unit of measure is *person-rem*). The population dose depends on the number of people at different locations. If the number of people increases in the future, the population dose estimate would also increase.

a) Lives at the location above where the highest concentration of radionuclides in the groundwater contamination plume crosses the boundary of the controlled area. The surface of the controlled area is defined as (40 CFR Part 197) the area, identified by passive institutional controls, that encompasses no more than 300 square kilometers. It must not extend farther south than 36º 40' 13.661" north latitude, in the predominant direction of groundwater flow, and no more than five kilometers from the repository footprint in any other direction

b) Has a diet and living style representative of the people who now reside in the Town of Amargosa Valley, Nevada. DOE must use projections based on surveys of the people residing in the Town of Amargosa Valley, Nevada, to determine their current diets and living styles and use the mean values of these factors in the assessments conducted for 40 CFR 197.20 and 197.25

c) Drinks 2 liters of water per day from wells drilled into the ground at the location specified in a).

While the RMEI is a regulatory definition for a specific location, impacts to individuals at two additional locations were evaluated using the lifestyle characteristics of the RMEI.

The analysis converted the annual committed effective dose equivalent, referred to as the annual individual dose, to the probability of contracting a fatal cancer (referred to as a latent cancer fatality) due to exposure to radioactive materials in the water. In addition, the analysis calculated population doses in person-rem for two different periods: for the 70-year lifetime at the time of the peak dose during the first 10,000 years after repository closure, and integrated over the first 10,000 years after repository closure. The analysis also converted the population dose to the expected number of latent cancer fatalities in the population. DOE based the analysis on the radionuclide inventories discussed in Section 5.1. However, the analysis included the entire carbon-14 inventory of the commercial spent nuclear fuel as a solid in the groundwater release models. Actually, 2 percent of the carbon-14 exists as a gas in the fuel (see Section 5.5). Thus, the groundwater models slightly overestimate (by 2 percent) the potential impacts from carbon-14.

The analysis studied potential consequences to individuals at three impact locations arising from waste mobilization and waterborne transport. A set of 300 model simulations were run using the GoldSim model (DIRS 155182-BSC 2001, all) for the RMEI location [about 18 kilometers (11 miles) from Yucca Mountain]. Each simulation used separate sets of sampled uncertainty parameters and generated an annual individual-dose profile for the 1 million years following repository closure. This set of simulations for the RMEI location, and some additional groundwater simulations (DIRS 154659-BSC 2001, Enclosure 3) provided the basis for calculating doses at 30 kilometers (19 miles) from the repository and at the discharge location near Franklin Lake Playa.

5.4.1 EXTENSION OF GROUNDWATER IMPACTS TO OTHER DISTANCES

The TSPA model estimates potential groundwater impacts for the RMEI location. This EIS provides groundwater impacts for two other important downgradient locations. These locations are 30 kilometers (19 miles), where most of the current population in the groundwater flow path is located, and 60 kilometers (37 miles), where the aquifer discharges to the surface (this location is also known as Franklin Lake Playa). The TSPA model used for the groundwater impacts at 18 kilometers (11 miles) is specifically designed for the RMEI location and is not directly usable to obtain reasonable estimates at farther distances. This is because conservative assumptions were embodied in the model, and the saturated zone transport model was designed primarily for the volcanic aquifer with characteristically very low mixing of waste in groundwater. Groundwater flow beyond the RMEI location occurs primarily in an alluvial medium with characteristically higher mixing, so plume concentrations would be reduced and a smaller quantity of radionuclides would be carried into the water usage wells.

Appendix I, Section I.4.5, details the development of distance scale factors using a three-dimensional analytical advection and dispersion transport model. Scaling factors were developed based on two criteria: attenuation of the peak concentrations in the plume and general increase in the cross-sectional area of the plume (that is, reduction of the average plume concentration). Two sets of factors were developed based on a large source size (characteristic of the repository footprint) and a small source size [10 meters by 10 meters (33 feet by 33 feet)]. The scaling factors were used to estimate *peak of the mean* and peak of the 95th-percentile annual individual doses and the groundwater concentrations at the two additional distances reported in Sections 5.4.2.1 and 5.4.2.2.

For the 10,000-year period of the nominal scenario, the dose would be attributable to the failure of a few waste packages. In this case, scaling factors based on a small size source were used. For the 1-million-year period, the release would be attributable to general releases over the whole repository area, so large source size scale factors were used. The factors based on the cross-section of the plume were chosen for the estimates. This was appropriate because the effect of water usage by the communities would be to cause significant mixing, and the more characteristic parameter would be the plume average concentration. Appendix I, Section I.4.5, includes scale factors for both approaches for comparison.

5.4.2 WATERBORNE RADIOLOGICAL RESULTS

This section discusses waterborne radiological consequences in relation to a higher-temperature repository operating mode and a lower-temperature operating mode. The individual and population dose calculations in this section were performed in a probabilistic manner using a volume of water necessary to operate 15 to 25 farms, representing a range of groundwater volumes from 1.1 million cubic meters to 4.2 million cubic meters (890 acre-feet to 3,400 acre-feet) with an average water demand of approximately 2.5 million cubic meters (2,000 acre-feet) per year. The final Nuclear Regulatory Commission regulations regarding a Yucca Mountain Repository state that the RMEI calculations should use an average water demand of 3,000 acre-feet [10 CFR 63.312(c)]. The 3.7-million-cubic-meter (3,000 acre-foot) water demand as specified by the Commission would result in dose estimates about two-thirds of the values in this section (DIRS 156743-Williams 2001, Section 6.3, pp. 12 and 13). The groundwater protection calculations in this section use 3,000 acre-feet water demand as called for in 40 CFR 197.31.

5.4.2.1 Waterborne Radiological Results for the Higher-Temperature Repository Operating Mode

The performance analysis indicated that for the first 10,000 years there would be very limited releases, attributable to early waste package failures due to waste package manufacturing defects, with very small radiological consequences (see Table 5-6). For the first 10,000 years after repository closure, the mean

Table 5-6. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode.

	Mean			95th-percentile		
Individual	Peak annual individual dose (millirem)	Time of peak (years)	Probability of an LCF[a]	Peak annual individual dose (millirem)	Time of peak (years)	Probability of an LCF[a]
At RMEI location[b]	0.00002[c]	4,900	6×10^{-10}	0.0001[d]	4,900	4×10^{-9}
At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC	~0
At discharge location[h]	~0[f]	NC	~0	~0[f]	NC	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this distance is 15 millirem.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. 30 kilometers = 19 miles.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

WHY ARE THE MEAN IMPACTS SOMETIMES HIGHER THAN THE 95TH-PERCENTILE IMPACTS?

The *mean* impact is the arithmetic average of the 300 impact results from simulations of total-system performance. The mean is not the same as the 50th-percentile value (the 50th-percentile value is called the *median*) if the distribution is *skewed*.

The performance results reported in this EIS come from highly skewed distributions. In this context, *skewed* indicates that there are a few impact estimates that are much larger than the rest of the impacts. When a large value is added to a group of small values, the large value dominates the calculation of the mean. The simulations reported in this EIS have mean impacts that are occasionally above the 90th-percentile and occasionally above the 95th percentile.

peak would be 0.00002 millirem and the 95th-percentile peak would be 0.0001 millirem. The peaks would be even smaller at greater distances. This result was lower than the Environmental Protection Agency standard, which allows up to a 15-millirem annual committed effective dose equivalent during the first 10,000 years. In the remainder of this chapter, the "annual committed effective dose equivalent" is referred to as the "annual individual dose."

Table 5-7 lists the population consequences associated with the peak annual individual dose listed in Table 5-6. The population size was based on the projected population numbers for 2035 in Figure 3-25 in Chapter 3 of this EIS. For these calculations, the analysis assumed that no contaminated groundwater would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors in Figure 3-25 were not considered to be exposed.

- 47 people would be exposed at the RMEI location [includes sectors from 12 to 28 kilometers (7 to 17 miles)]

- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository [includes sectors from 28 to 44 kilometers (17 to 27 miles)]

Table 5-7. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode.

	Mean		95th-percentile	
Impact	Population dose (person-rem)	Population LCF[a]	Population dose (person-rem)	Population LCF[c]
Peak 70-year lifetime	0.006	0.000003	0.04	0.00002
Integrated over 10,000 years	0.5	0.0002	0.6	0.0003

a. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

- 69,500 people would be exposed at the discharge location about 60 kilometers (37 miles) downgradient from the potential repository [includes sectors from 44 to 80 kilometers (27 to 50 miles)]

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of lifestyles and residence locations far into the future.

The values in Table 5-7 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water before calculating the population dose.

The small consequences listed in Tables 5-6 and 5-7 would result from the durability of the waste packages; most of which would remain intact significantly longer than 10,000 years. The outer layer of the waste package would be subject to a very low average corrosion rate, but there is a high degree of uncertainty in the value of that average corrosion rate. Model simulations incorporated a small number of waste package failures within 10,000 years due to manufacturing defects; the dose results in Tables 5-6 and 5-7 during this period would result directly from these early failures.

The radionuclides that would contribute the most to individual dose in 10,000 years would be technetium-99, carbon-14 dissolved in groundwater, and iodine-129. For example, the mean consequence at 18 kilometers (11 miles) has technetium-99 contributing 77 percent of the total annual individual dose rate, carbon-14 contributing 16 percent, and iodine-129 contributing 7 percent. While the atmospheric analysis in this EIS assumed that 2 percent of the carbon-14 migrated as gas in the form of carbon dioxide (see Section 5.5 for more details), the groundwater modeling for this waterborne radiological consequences analysis conservatively assumed that all of the carbon-14 migrated in the groundwater.

Table 5-8 lists impacts for the post-10,000-year period. The table lists the mean and 95th-percentile peak annual individual dose and the times of the associated peaks at three locations. The mean and 95th-percentile annual individual doses during 1 million years following repository closure are shown in Figure 5-4. The multiple peaks occurring 200,000 years or more after repository closure are driven by transitions between climate states.

Table 5-8. Impacts for an individual from groundwater releases of radionuclides during 1 million years after repository closure for the higher-temperature repository operating mode.

Individual	Mean		95th-percentile	
	Peak annual individual dose (millirem)	Time of peak (years)	Peak annual individual dose (millirem)	Time of peak (years)
At RMEI location[a]	150[b]	480,000	620[c]	410,000
At 30 kilometers[d]	100[e]	NC[f]	420[e]	NC
At discharge location[g]	59[e]	NC	240[e]	NC

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. 30 kilometers = 19 miles.
e. Estimated using scale factors as described in Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

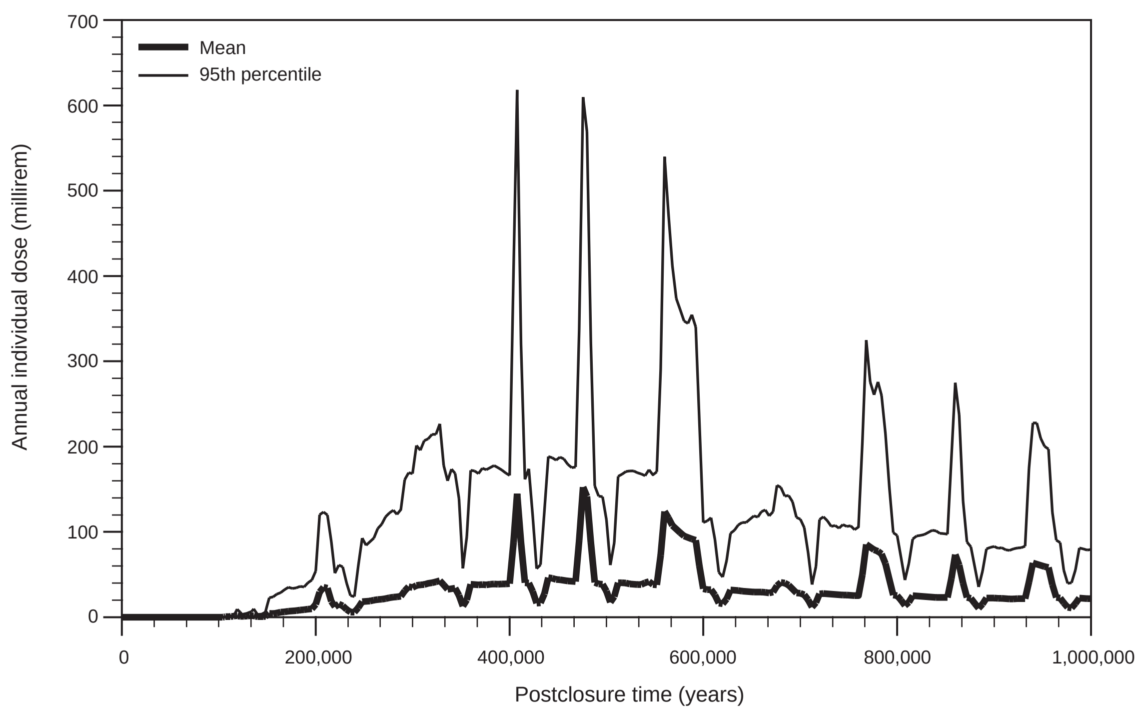

Figure 5-4. Mean and 95th-percentile (based on 300 simulations of total system performance, each using random samples of uncertain parameters) annual individual dose at the RMEI location during 1 million years after repository closure for the nominal scenario under the higher-temperature repository operating mode.

The simulations were ended after 1 million years largely because further radioactive decay would continue to decrease the annual individual dose even for very long-lived radionuclides. The peak annual individual dose usually coincided with the occurrence of a wetter climate period.

The radionuclides that would contribute the most to the peak annual individual dose in 1 million years would be neptunium-237 and plutonium-242. The mean peak annual individual dose at the RMEI location would have neptunium-237 contributing 61 percent of the total annual individual dose, plutonium-242 contributing 13 percent, actinium-227 contributing 5 percent, thorium-229 and uranium-234 each contributing 3 percent, and uranium-233, lead-210, and radium-226 each contributing 2 percent. The plutonium isotopes contributing to dose would be due to colloidal transport of plutonium, not transport of plutonium as a dissolved element in groundwater.

With respect to the groundwater protection standards in 40 CFR 197.30, both the mean and 95th-percentile estimated levels during the 10,000-year regulatory period would be hundreds of thousands of times less than the regulatory limits (see Table 5-9).

Table 5-9. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the higher-temperature repository operating mode.

Radionuclide or type of radiation emitted	EPA limit[b]	Mean peak[c]	95th-percentile peak[d]
Combined radium-226 and radium-228[e] (picocuries per liter)	5	1.0 (1×10^{-11})[f]	1.0 (2×10^{-11})[f]
Gross alpha activity (including radium-226 but excluding radon and uranium)[e] (picocuries per liter)	15	0.4 (2×10^{-8})[f]	0.4 (1×10^{-8})[f]
Combined beta- and photon-emitting radionuclides,[g] millirem per year to the whole body or any organ,[h] based on drinking 2 liters[i] of water per day from the representative volume	4	2×10^{-5}	1×10^{-4}

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits at 40 CFR 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. Does not include natural background radiation.
h. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.
i. 2 liters = 0.53 gallon.

5.4.2.2 Waterborne Radiological Results for the Lower-Temperature Repository Operating Mode

DOE conducted performance studies for the lower-temperature repository operating mode. This section discusses groundwater impacts for the lower-temperature operating mode. The performance analysis indicated that for the first 10,000 years there would be very limited releases, attributable to early waste package failures due to waste package manufacturing defects, with very small radiological consequences (see Table 5-10). For the first 10,000 years after repository closure, the mean peak would be 0.00001 millirem and the 95th-percentile peak would be 0.0001 millirem. The peaks would be even smaller at greater distances. This result was compared to the EPA standard, which allows up to a 15-millirem annual individual dose during the first 10,000 years.

Table 5-11 lists the population consequences associated with the peak annual individual dose listed in Table 5-10. The population size was based on the population numbers projected for the year 2035 in Figure 3-25 in Chapter 3 of this EIS. For these calculations, the analysis assumed that no contaminated groundwater would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors in Figure 3-25 were not considered to be exposed.

Table 5-10. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the lower-temperature repository operating mode.

Individual	Mean: Peak annual individual dose (millirem)	Mean: Time of peak (years)	Mean: Probability of an LCF[a]	95th-percentile: Peak annual individual dose (millirem)	95th-percentile: Time of peak (years)	95th-percentile: Probability of an LCF[a]
At RMEI location[b]	0.00001[c]	3,400	4×10^{-10}	0.0001[d]	5,000	3×10^{-9}
At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC	~0
At discharge location[h]	~0[f]	NC	~0	~0[f]	NC	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer for individuals, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this location is 15 millirem.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. 30 kilometers = 19 miles.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

Table 5-11. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the lower-temperature repository operating mode.

Impact	Mean: Population dose (person-rem)	Mean: Population LCF[a]	95th-percentile: Population dose (person-rem)	95th-percentile: Population LCF[c]
Peak 70-year lifetime	0.004	0.000002	0.03	0.00002
Integrated over 10,000 years	0.3	0.0002	0.4	0.0002

a. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

- 47 people would be exposed at the RMEI location (includes sectors from 12 to 28 kilometers)

- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository (includes sectors from 28 to 44 kilometers)

- 69,500 people would be exposed at the discharge location about 60 kilometers (37 miles) downgradient from the potential repository (includes sectors from 44 to 80 kilometers)

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of lifestyles and residence locations far into the future.

The values in Table 5-11 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre-feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water before calculating the population dose.

The small consequences listed in Tables 5-10 and 5-11 would result from the durability of the waste packages; most of which would remain intact significantly longer than 10,000 years. The outer layer of the waste package would be subject to a very low average corrosion rate, but there is a high degree of uncertainty in the value of that average corrosion rate. Model simulations incorporated a small number of waste package failures within 10,000 years due to manufacturing defects; the dose results in Table 5-10 and 5-11 during this period would result directly from these early failures.

The radionuclides that would contribute the most to individual dose in 10,000 years would be technetium-99, carbon-14 dissolved in groundwater, and iodine-129. For example, the mean consequence at 18 kilometers (11 miles) has technetium-99 contributing 63 percent of the total individual dose rate, carbon-14 contributing 25 percent, and iodine-129 contributing 10 percent. While the atmospheric analysis in this EIS assumed that 2 percent of the carbon-14 migrated as gas in the form of carbon dioxide (see Section 5.5 for more details), the groundwater modeling for this waterborne radiological consequences analysis conservatively assumed that all of the carbon-14 migrated in the groundwater.

Table 5-12 lists impacts for the post-10,000-year period as peak annual doses. The table lists the mean and 95th-percentile peak annual individual dose and the times of the associated peaks at three locations. The mean and 95th-percentile annual individual doses during 1 million years following repository closure are shown in Figure 5-5. The multiple peaks occurring 200,000 years or more after repository closure are driven by transitions between climate states.

Table 5-12. Impacts for an individual from groundwater releases of radionuclides during 1 million years after repository closure for the lower-temperature repository operating mode.

	Mean		95th-percentile	
Individual	Peak annual individual dose (millirem)	Time of peak (years)	Peak annual individual dose (millirem)	Time of peak (years)
At RMEI location[a]	120[b]	480,000	510[c]	410,000
At 30 kilometers[d]	83[e]	NC[f]	350[e]	NC
At discharge location[g]	48[e]	NC	240[e]	NC

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. 30 kilometers = 19 miles.
e. Estimated using scale factors as described in Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

The simulations were ended after 1 million years largely because further radioactive decay would continue to decrease annual individual dose even for very long-lived radionuclides. The peak annual individual dose usually coincided with the occurrence of a wetter climate period.

The radionuclides that would contribute the most to the peak annual individual dose in 1 million years would be neptunium-237 and plutonium-242. The mean peak dose at 18 kilometers (11 miles) would have neptunium-237 contributing 63 percent of the total individual dose rate, plutonium-242 contributing 12 percent, actinium-227 contributing 5 percent, thorium-229 and uranium-234 each contributing 3 percent, and uranium-233, lead-210, and radium-226 each contributing 2 percent. The plutonium isotopes contributing to dose would be due to colloidal transport of plutonium, not transport of plutonium as a dissolved element in groundwater.

With respect to the groundwater protection standards in 40 CFR 197.30, both the mean and 95th-percentile estimated levels during the 10,000-year regulatory period would be hundreds of thousands of times less than the regulatory limits (see Table 5-13).

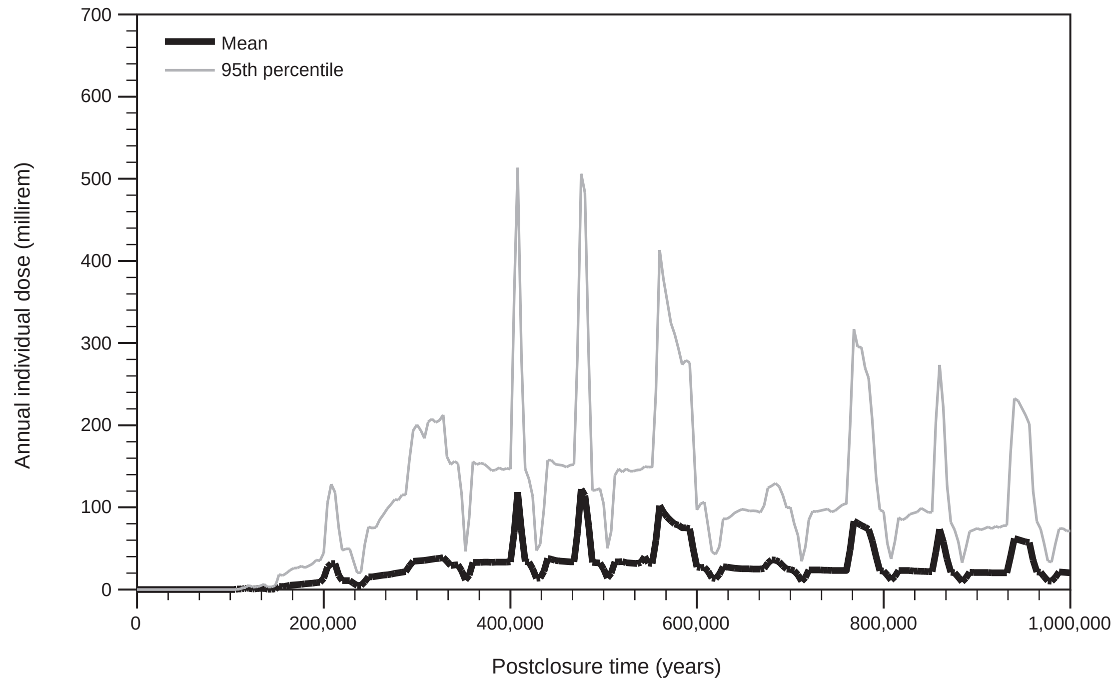

Figure 5-5. Mean and 95th-percentile (based on 300 simulations of total system performance, each using random samples of uncertain parameters) annual individual dose at the RMEI location during 1 million years after repository closure for the nominal scenario under the lower-temperature repository operating mode.

Table 5-13. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the lower-temperature repository operating mode.

Radionuclide or type of radiation emitted	EPA limit[b]	Mean peak[c]	95^{th}-percentile peak[d]
Combined radium-226 and radium-228[e] (picocuries per year)	5	1 (2×10^{-12})[f]	1 (1×10^{-11})[f]
Gross alpha activity (including radium-226 but excluding radon and uranium)[e] (picocuries per year)	15	0.4 (3×10^{-8})[f]	0.4 (2×10^{-8})[f]
Combined beta- and photon-emitting radionuclides,[g] millirem per year to the whole body or any organ,[h] based on drinking 2 liters[i] of water per day from the representative volume	4	1×10^{-5}	7×10^{-5}

a. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits set forth in 40 CFR 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. Does not include natural background radiation.
h. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.
i. 2 liters = 0.53 gallon.

5.4.2.3 Alternative Dosimetry Methods

The long-term postclosure groundwater impacts are estimated using ICRP-30 (DIRS 110386-ICRP 1979, all; DIRS 110351-ICRP 1980, all; DIRS 110352-ICRP 1981, all) domestic methods. It has been suggested by an international peer review that the more recent ICRP-72 methods (DIRS 152446-ICRP 1996, all), as are used internationally for such estimates, would be more appropriate. Sensitivity studies indicate the peak dose estimates would be about a factor of 4 lower if the ICRP-72 analytical methods were applied (DIRS 157151-BSC 2001, Appendix L. pp. L-31 to L-33).

5.5 Atmospheric Radiological Consequences

After DOE closed the repository, there would be limited potential for releases to the atmosphere because the waste would be isolated far below the ground surface. Still, the rock is porous and does allow gas to flow, so the analysis must consider possible airborne releases. The only radionuclide in the analysis after screening with a potential for gas transport is carbon-14 in the form of carbon dioxide. Iodine-129 can exist in a gas phase, but DOE expects it would dissolve in the groundwater rather than migrate as a gas. The solubility of iodine-129 is a great deal higher than that of carbon dioxide, and the water is already saturated in carbon dioxide because of interaction with carbonate rocks. After the carbon-14 escaped as carbon dioxide from the waste package, it would flow through the rock. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in a gas phase in the space (or gap) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). The atmospheric model used a gas-phase inventory of 0.122 curie of carbon-14 per waste package of commercial spent nuclear fuel at the time of emplacement. The atmospheric model estimated human health impacts for the population in the 80-kilometer (50-mile) region surrounding the repository.

In addition, DOE considered the possible impacts from the release of radon from the repository. Radon is a decay product of uranium and would be generated for as long as any uranium remained in the repository. Based on gas flow studies, DOE believes that radon would decay before it reached the ground surface. Appendix I, Section I.7.3, contains a more detailed screening discussion.

5.5.1 SOURCE TERM

The calculation of regional doses used an estimate of the annual release rate of carbon-14. The analysis based the carbon-14 release rate on the estimated time line of waste package container failures for the higher-temperature repository operating mode nominal scenario. If the same analysis were performed using waste package failures for the lower-temperature operating mode, the results would be nearly the same with slightly lower impacts. The expected number of commercial spent nuclear fuel waste package failures as a function of time was used to estimate the carbon-14 release rates after repository closure. The amount of material released from each package as a function of time was reduced to account for radioactive decay. As for the waterborne releases described in Section 5.4.1, credit was taken for the intact zirconium alloy cladding (on approximately 99 percent by volume of the spent nuclear fuel at emplacement) delaying the release of gas-phase carbon-14 (DIRS 153849-DOE 2001, p. 3-7). The remaining 1 percent by volume of the spent nuclear fuel either would have stainless-steel cladding (which degrades much more quickly than zirconium alloy) or would already have failed in the reactor. Thus, gas-phase releases from this fuel would have occurred before it was shipped to the repository. The maximum annual-release rate would occur about 1,700 years after repository closure, and the estimated maximum release rate would be 3.3 microcuries per year of carbon-14.

5.5.2 ATMOSPHERIC CONSEQUENCES TO THE LOCAL POPULATION

DOE used the *GENII* program (DIRS 100953-Napier et al. 1988, all) to model the atmospheric transport and human uptake of the released carbon-14 for the 80-kilometer (50-mile) population dose calculation.

Doses to the regional population around Yucca Mountain from carbon-14 releases were estimated using the population distribution shown in Chapter 3, Figure 3-25, which indicates that 76,000 people would live in the region surrounding Yucca Mountain in 2035. The computation also used current (1993 to 1996) annual average meteorology (see Appendix I, Table I-33). GENII calculated a dose factor of 4.6×10^{-9} person-rem per microcurie per year of release. For a 3.3-microcurie-per-year release, this corresponds to a maximum 80-kilometer annual population dose of 1.5×10^{-8} person-rem. This dose corresponds to 7.5×10^{-12} latent cancer fatality in the regional population of 76,000 persons during each year at the maximum carbon-14 release rate. This annual population radiological dose corresponds to a 70-year lifetime radiological population dose of 1.1×10^{-6} person-rem, which corresponds to 5.3×10^{-10} latent cancer fatality during the 70-year period of the maximum release.

5.5.3 ATMOSPHERIC CONSEQUENCES TO AN INDIVIDUAL

For a constant-sized population living only at the locations in the population distribution shown in Chapter 3, Figure 3-25, a maximally exposed individual for airborne releases would reside 24 kilometers (15 miles) south of the repository. The location for maximum dose is dependent on wind speed and wind direction, and is only considered for those locations where people currently reside (it was not a predetermined location). An individual radiological dose factor of 5.6×10^{-14} rem per microcurie per year of release was calculated using the GENII code for this location. For a 3.3-microcurie-per-year maximum release rate, the individual maximum radiological dose rate would be 1.8×10^{-13} rem per year, corresponding to a 9.2×10^{-17} probability of a latent cancer fatality. The 70-year lifetime dose would be 1.3×10^{-11} rem, representing a 6.4×10^{-15} probability of a latent cancer fatality.

5.6 Consequences from Chemically Toxic Materials

A number of nonradioactive materials that DOE would place in the repository will degrade over time into materials that are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials.

Appendix I, Section I.3 discusses the inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action by element. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1) identified which of the chemically toxic materials could pose a potential risk to human health. Chromium, molybdenum, nickel, and vanadium were identified as posing such a potential risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. This analysis makes the conservative assumption that all chromium dissolves in hexavalent form.

It should also be noted that all of the chromium, molybdenum, nickel, and vanadium considered are elements contained in the metals used to package the waste and support the packages. None of the materials inside the waste packages were considered because, except for about three packages, all packages would last for more than 50,000 years.

Table 5-14 summarizes the results of the bounding analysis. In some cases a Maximum Contaminant Level or Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to the intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day.

The bounding consequence analysis estimated that the maximum peak concentration of chromium in groundwater used at exposure locations would be 0.01 milligram per liter. There are two measures for comparing human health effects for chromium. When the Environmental Protection Agency established its Maximum Contaminant Level Goals, it considered safe levels of contaminants in drinking water and

Table 5-14. Consequences from waterborne chemically toxic materials release during 10,000 years after repository closure estimated using a bounding calculation.

Material	Concentration in well water (milligram per liter)	Maximum Contaminant Level Goal[a] (milligram per liter)	Intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Chromium (VI)	0.01	0.1	0.0004	0.005[b]
Molybdenum	0.009	NA[c]	0.0003	0.005[d]
Nickel	0.04	NA	0.001	0.02[e]
Vanadium	0.0002	NA	0.000006	0.007[f]

a. 40 CFR 141.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

the ability to achieve these levels with the best available technology. The Maximum Contaminant Level Goal for chromium is 0.1 milligram per liter (40 CFR 141.51). The bounding concentration is well below the Maximum Contaminant Level Goal for chromium (about one-tenth of this limit). The other measure for comparison is the reference dose factor for chromium, which is an intake of 0.0004 milligram of chromium per kilogram of body mass per day (DIRS 148224-EPA 1999, all). The reference dose factor represents a level of intake that has no adverse effect on humans. It can be converted to a threshold concentration level for drinking water. The conversion yields essentially the same concentration for the reference dose factor as the Maximum Contaminant Level Goal. At present, the bounding estimate of groundwater concentration of hexavalent chromium cannot be expressed in terms of human health effects (for example, latent cancer fatalities). The carcinogenicity of hexavalent chromium by the oral route of exposure has not been determined because of a lack of sufficient epidemiological or toxicological data (DIRS 148224-EPA 1999, all; DIRS 101825-EPA 1998, p. 48).

The estimated bounding concentration of molybdenum in groundwater used at exposure locations would be 0.009 milligram per liter. There is no Maximum Contaminant Level Goal for molybdenum but intake can be compared to the Oral Reference Dose. The intake rate from drinking 2 liters (0.53 gallon) per day of contaminated water by a 70-kilogram (154-pound) person would be 0.0003 milligram per kilogram per day. This is well below the Oral Reference Dose of 0.005 milligram per kilogram per day (DIRS 148228-EPA 1999, all).

The estimated bounding concentration of nickel in groundwater used at exposure locations would be 0.04 milligram per kilogram. There is no Maximum Contaminant Level Goal available for nickel but intake can be compared against the Oral Reference Dose. The intake rate from drinking 2 liters (0.53 gallon) per day of contaminated water by a 70-kilogram (154-pound) person would be 0.001 milligram per kilogram per day. This is well below the Oral Reference Dose of 0.02 milligram per kilogram per day.

The estimated bounding concentration of vanadium in groundwater used at exposure locations would be 0.0002 milligram per liter. There is no Maximum Contaminant Level Goal available for vanadium, but intake can be compared to the Oral Reference Dose. The intake rate from drinking 2 liters (0.53 gallon) per day of contaminated water by a 70-kilogram (154-pound) person would be 0.000006 milligram per kilogram per day. This is well below the Oral Reference Dose of 0.007 milligram per kilogram per day.

Because the estimated bounding concentrations of chromium, molybdenum, nickel and vanadium in well water would be below the Maximum Contaminant Level Goal or yield intakes well below the Oral Reference Dose, there is no further need to refine the calculation to account for physical processes that would limit mobilization of those materials or delay and dilute them during transport in the geosphere.

5.7 Consequences from Disruptive Events

The postclosure performance estimates discussed in Sections 5.4, 5.5, and 5.6 include the possible effects of changing climate and seismic events but do not address other events that could physically disturb the repository. In general, disruptive events have identifiable starting and ending times, in contrast to continuous processes such as corrosion. The disruptive events examined in this section are an *inadvertent intrusion* into the repository by a drilling crew and basaltic igneous (volcanic) activity.

5.7.1 HUMAN INTRUSION SCENARIO

DOE examined the consequences of a human intrusion scenario involving inadvertent drilling.

The human intrusion scenario analyzed in this EIS is consistent with the requirements of 40 CFR Part 197. The stylized human intrusion scenario is summarized as follows:

- The human intrusion would occur 30,000 years after permanent repository closure when there was enough degradation in waste packages that the driller might not detect the penetration.
- The intrusion would result in a single, nearly vertical borehole that penetrated a waste package and extended down to the saturated zone.
- Current practices for resource exploration would be used to establish properties (e.g., borehole diameter, drilling fluid composition).
- The borehole would not be adequately sealed and would permit infiltrating water and natural degradation processes to modify the borehole gradually.
- Only releases through the borehole to the saturated zone were considered; hazards to the drillers or to the public from material brought to the surface by the assumed intrusion were not included.

The human intrusion results were calculated probabilistically, analogous to the nominal scenario calculations for waterborne radioactive material releases. The calculations were carried out for the higher-temperature repository operating mode. For this stylized intrusion scenario, there would be no difference for the lower-temperature operating mode because exactly one waste package is intersected for both operating modes and its inventory is moved to the saturated zone where further transport does not depend on repository operating mode. Figure 5-6 shows the mean and 95th-percentile annual individual dose for 1 million years resulting from a human intrusion 30,000 years after repository closure for the set of 300 simulations. The values in Figure 5-6 represent the dose from a single waste package, and are not combined with releases for other waste packages that would fail due to other processes. The peak of the mean annual individual dose from human intrusion would be 0.002 millirem, occurring a short time after 100,000 years after repository closure. These results indicate that the repository would be sufficiently robust and resilient to limit releases caused by human intrusion to values well below the 15-millirem annual individual dose standard.

The analysis did not combine the results of the disruptive igneous event scenario with the results of the human intrusion scenario. However, combined results can be approximated by adding the results of the human intrusion analysis to that of the disruptive igneous event scenario, which would result in a total combined maximum dose. Based on the results presented in this section and Section 5.7.2, the highest mean annual individual dose that would result from an intrusion would be less than one-tenth of the radiological dose from a disruptive igneous event.

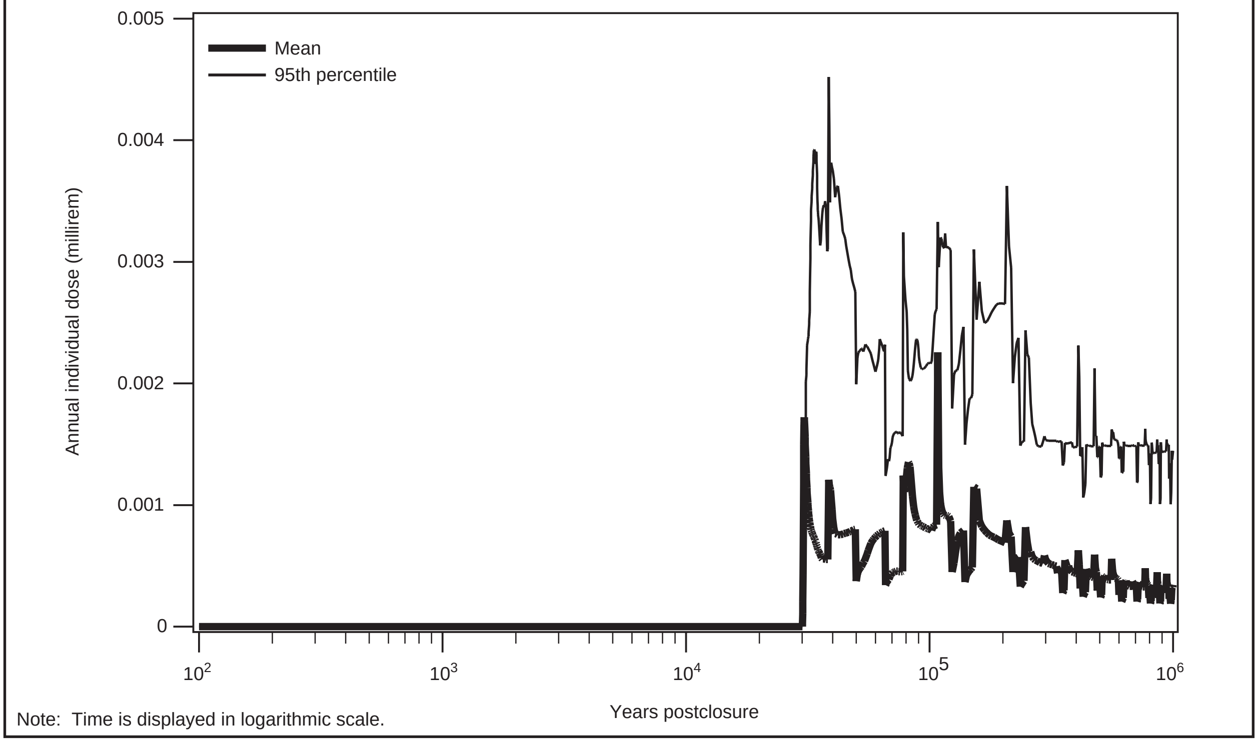

Figure 5-6. Mean and 95th-percentile annual individual dose at the RMEI location resulting from human intrusion 30,000 years after repository closure under the higher-temperature repository operating mode.

A sensitivity study where the human intrusion occurs at 100 years after repository closure has also been conducted (DIRS 157307-BSC 2001, Enclosure 1).

5.7.2 IGNEOUS ACTIVITY SCENARIO

The analysis of igneous activity utilized a model for volcanic eruptions that would intersect drifts and bring waste to the surface, and a model for igneous intrusions that would damage waste packages, thereby exposing radionuclides to groundwater for transport.

5.7.2.1 Volcanic Eruption Events

The conceptualization of a volcanic eruption at Yucca Mountain envisioned an igneous dike that would rise through the Earth's crust and intersect one or more repository drifts. An eruptive conduit could form somewhere along the dike as it neared the land surface, feeding a volcano at the surface. Waste packages in the direct path of the conduit would be destroyed, and the waste in those packages would subsequently be entrained in the eruption. Volcanic ash would be contaminated, erupted, and transported by wind. Ash would settle out of the plume as it was transported downwind, resulting in an ash layer on the land surface. Members of the public would then receive a radiation dose from exposure pathways associated with the contaminated ash layer.

Model development included the selection of conservative assumptions about the event, selection of input parameter distributions characterizing important physical properties of the system, and use of a computational model to calculate entrainment of waste in the erupting ash. Each intrusive event (a swarm of one or more dikes) was assumed to generate one or more volcanoes somewhere along its length, but eruptions would not need to occur within the repository footprint. Approximately 77 percent of intrusive events that intersected the repository would be associated with one or more surface eruptions within the repository footprint. The number of eruptive conduits (volcanoes) is independent of the number of dikes in a swarm. Characteristics of the eruption such as eruptive power, style (violent versus normal), velocity, duration, column height, and total volume of erupted material, are included in the analysis.

5.7.2.2 Groundwater Transport of Radionuclides Following Igneous Intrusion Event

The conceptualization of radionuclide release and transport away from waste packages damaged by an igneous intrusion that intersected the repository is similar to the nominal model for radionuclide release and transport (discussed in Section 5.4), but was modified to include the intrusion. The igneous intrusion groundwater transport model includes a set of input parameters to define a modified source term for use in the nominal scenario flow and transport model. There are three main components to the model: the behavior of the waste packages and other engineered barrier system elements damaged because of their proximity to an igneous intrusion; groundwater flow and radionuclide transport away from the waste packages; and calculation of the number of waste packages damaged as a result of the igneous intrusion.

The analysis assumed that waste packages close to the point of intrusion would be so damaged that they would provide no further protection for the waste. Actual conditions would be uncertain, and damage probably would range from moderate to extensive. Nominal models for radionuclide mobilization and transport were used even though conditions would change in the drift following intrusion. All waste in the most severely damaged packages would be immediately available for transport in the unsaturated zone, depending on solubility limits and the availability of water, which was determined using the seepage model for nominal performance. The thermal, chemical, and mechanical effects of the intrusion on the drift environment were neglected. No credit was taken for water diversion by the remnants of the drip shield or waste package, and cladding was assumed to be fully degraded. Actual thermal, chemical, hydrological, and mechanical conditions in the drift following igneous intrusion are unknown, although conservatively assuming that the engineered barriers would have completely failed is sufficient to compensate for the uncertainty associated with conditions in the drift.

5.7.2.3 Results for Igneous Activity Scenario

The approach taken to calculate doses resulting from the igneous activity scenario is consistent with the probabilistic methodology described in Nuclear Regulatory Commission guidance (DIRS 103760-NRC 1998, all; DIRS 119693-Reamer 1999; all). Scenario consequences are multiplied ("weighted") by the probability of occurrence of the scenario to yield an appropriate estimate of the overall risk posed by low-probability events. The probability of igneous activity is extremely low (the mean annual probability is 1.6×10^{-8}), and the probability of more than one igneous disruption occurring during the next 100,000 years is far below the level of concern. Therefore, the analysis considered only a single igneous eruption within the repository during the next 100,000 years, occurring with a mean 100,000-year probability of 1.6×10^{-3}. The year in which that eruption could occur is uncertain; therefore, the igneous eruption scenario was evaluated as if it were many different eruptive scenarios, each occurring in a different 25-year time interval, and each occurring with a probability 25 times that of the annual probability. The average dose resulting from igneous disruption was determined by calculating doses resulting from igneous events in each 25-year period, multiplying by the probability (mean 25-year probability of 4.0×10^{-7}), and adding the doses from each *disruptive event*. For computational efficiency, igneous intrusions that would not result in a surface eruption were simulated using a simpler approach in which the time of intrusion was sampled randomly from the 100,000-year period, and the probability associated with each simulation is the full 100,000-year probability of 1.6×10^{-3}. Probability-weighted doses from both eruptive and intrusive events were added together to give the total dose from igneous disruption.

The average doses from igneous activity calculated in this manner incorporate uncertainties regarding the time at which the igneous event could occur, and account for the reality that, as time passed, the likelihood would increase that igneous disruptions could have already occurred. For example, a person living downwind from Yucca Mountain 10,000 years after repository closure would have a mean probability of 1.6×10^{-4} of receiving a radiation dose from soil contaminated by an igneous event sometime in the past. The probability-weighted average dose emphasizes the overall risk to a person living downwind from Yucca Mountain, in terms of both the likelihood and consequences of the igneous activity scenario.

Figure 5-7 shows the mean probability-weighted dose histories representing possible doses to an individual for the higher-temperature repository operating mode. The figure also shows the nominal scenario for comparison. The igneous activity scenario is only simulated to 100,000 years because the nominal scenario impacts dominate after that time. These summary curves are based on 5,000 individual dose histories calculated using different sets of uncertain input parameters in the model. For approximately the first 20,000 years, the dose history is a smooth curve that is dominated by the effects of volcanic eruption. The probability-weighted mean annual individual dose during this period would reach a peak of approximately 0.1 millirem about 300 years after repository closure, and then decline because of radioactive decay of the relatively shorter-lived radionuclides that contributed to doses from the ash fall exposure pathway. The major contributors to the eruptive dose would be americium-241, plutonium-238, plutonium-239, and plutonium-240. Strontium-90 would be a significant contributor at extremely early times, but would drop off rapidly because of radioactive decay (*half-life* of 29.1 years). Inhalation of resuspended particles in the ash layer would be the primary exposure pathway during this period, and the smooth decline of the mean dose curve from approximately 300 to 2,000 years would result from decay of americium-241 (half-life of 432 years). From approximately 20,000 years after closure, the mean igneous dose would be dominated by groundwater releases from packages damaged by igneous intrusions that did not erupt to the surface. The irregular shape of the curve from this point forward is in part a result of the groundwater transport processes, and in part reflects the occurrence of intrusive events at random times, rather than the prescribed intervals used for extrusive simulations. The intrusive event could occur at any time, and the first appearance of groundwater doses in the mean curve at approximately 20,000 years reflects retardation during transport, rather than the absence of intrusions at earlier times. Results for the lower-temperature operating mode would be essentially identical to those for the higher-temperature mode because the probability of an igneous intrusion interacting with waste packages is reduced for the wider waste package spacing. However, the overall probability of an igneous intrusion intersecting the potential repository would increase because of a larger repository emplacement area.

The dose history for the igneous activity scenario in Figure 5-7 is presented as a probability-weighted annual dose resulting from events occurring at uncertain times throughout the period of simulation. This approach to calculating and displaying the probability-weighted annual doses is consistent with the approach specified by 40 CFR Part 197 and is required for determination of the overall expected annual dose. However, displays of the probability-weighted annual dose do not allow direct interpretation of the conditional annual dose, which is the annual dose an individual would receive if a volcanic event occurred at a specified time. For conditional analyses, the probability of the event is set equal to one, and the time of the event is specified. Conditional results do not provide a meaningful estimate of the overall risk associated with igneous activity at Yucca Mountain, but they provide insights into the magnitude of possible consequences for specific sets of assumptions. A sensitivity calculation was performed to provide results for this conditional case (DIRS 154659-BSC 2001, pp. 3-47 to 3-48). Conditional mean annual dose histories were calculated for eruptive events at 100, 500, 1,000, and 5,000 years. The conditional mean dose in the first year after an eruptive event at 100 years after repository closure is approximately 13 rem. The conditional dose in the first year after an eruption decreases to approximately one-half this level for an eruption 500 years after closure, and is approximately 10 percent of this value for an eruption 5,000 years after closure. This calculation was made with a previous TSPA model (DIRS 153246-CRWMS M&O 2000, all) that has some differences from the model used elsewhere in this EIS for long-term performance (DIRS 157307-BSC 2001, Enclosure 1). The differences that affect the analysis described above are that dose factors were revised to conform to 40 CFR Part 197 and the

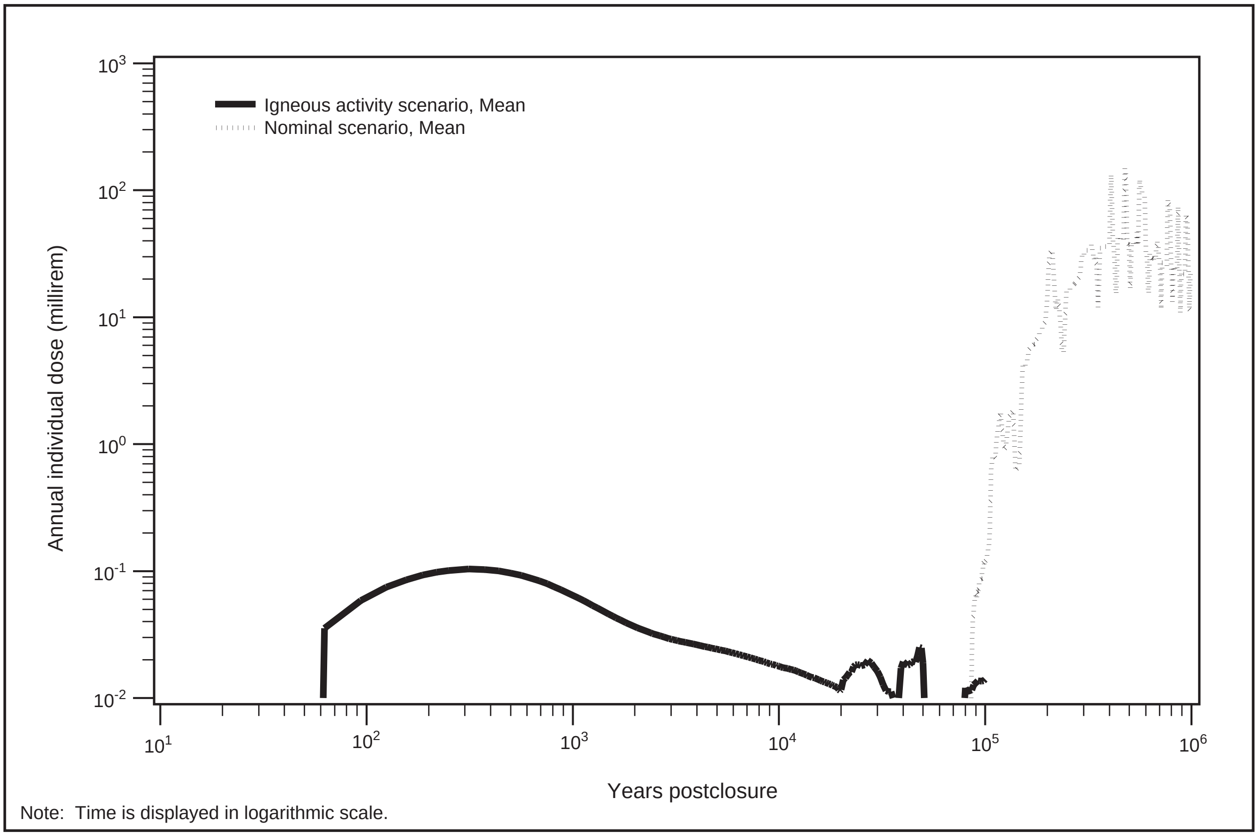

Figure 5-7. Mean (based on 5,000 simulations of total system performance, each using random samples of uncertain parameters) annual individual dose at the RMEI location resulting from igneous disruptions under the higher-temperature repository operating mode, with the mean dose history at this location for the higher-temperature operating mode nominal scenario.

distance analyzed is 20 kilometers rather than 18 kilometers from the repository. These changes would be expected to increase the dose values at 100 years and 500 years by a factor of between 2 and 3. The results at the later times would increase by about 20 percent.

5.8 Nuclear Criticality

This section examines the probability of isolated nuclear criticality events in waste packages and in surrounding rock. A short tutorial on the physics of nuclear criticality and the associated conditions that can cause such an event is provided in the Science and Engineering Report (DIRS 153849-DOE 2001, pp. 4-406 to 4-409). The tutorial provided in the Science and Engineering Report identifies the required conditions for nuclear criticality at the proposed repository. One of the required conditions for nuclear criticality is the presence of a moderator such as liquid water. Liquid water could only be introduced into the waste package if the waste package failed. The following information is excerpted from the Yucca Mountain Science and Engineering Report (DIRS 153849-DOE 2001, pp. 4-412 to 4-416).

5.8.1 PROBABILITY OF INTERNAL CRITICALITY FOR COMMERCIAL SPENT NUCLEAR FUEL

Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. Each package would contain a neutron absorber that would have the important function of capturing neutrons and helping to prevent a criticality. The conditions of waste package failure and entrance of liquid water are required for internal criticality. The probability of these conditions occurring would be very small. The probability of the loss of neutron absorber would increase with time after 10,000 years. As the internal components of a waste package degraded, the assemblies in the package would collapses reducing the spacing between the fuel rods. This would reduce the probability of criticality because of the reduced volume between fuel rods available for the moderator to fill. Another factor tending to reduce the probability of criticality with time would be the eventual breach of the bottom of the waste package, which would drain most of the water in the waste package that acted as a moderator. The potential for criticality of commercial spent nuclear fuel would be maximized when the internal basket was fully degraded, but with the assemblies remaining intact and no breach of the bottom of the waste package. Under these circumstances, the calculated probability of a critical event within the total inventory of the 21-PWR Absorber Plate waste packages would be less than 2×10^{-7} in 10,000 years (after closure of the repository). The 21-PWR Absorber Plate waste package was chosen for criticality calculations because it is the design for fuel with the highest reactivity and thus would be expected to have the highest probability of criticality.

5.8.2 PROBABILITY OF INTERNAL CRITICALITY FOR CODISPOSED DOE SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. Evaluations have been performed of the criticality potential of waste packages that would contain high-level radioactive waste glass and certain types of codisposed DOE spent nuclear fuel. The probability of criticality for these fuel types would generally be less than the small value of 2×10^{-7} for commercial spent nuclear fuel. The primary reasons are the lower fissile loading per waste package and the greater flexibility to install neutron absorber due to smaller fuel mass per waste package.

5.8.3 PROBABILITY OF CRITICALITY FOR THE IMMOBILIZED PLUTONIUM WASTE FORM

Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. The design of the immobilized plutonium waste form makes criticality virtually impossible. The degradation rate of the ceramic waste form would be so slow that, in the unlikely event that the waste package was breached and filled by a continuous dripping of water, it would be nearly 50,000 years after emplacement before enough of this waste form had degraded to permit any significant separation of the uranium and plutonium from the gadolinium and hafnium neutron absorbers. Even after degradation of the waste form, the gadolinium and hafnium are generally less soluble than the fissile material, so they would not be transported out of the waste package while the fissile material remains. Even if extremely unlikely chemistry conditions occurred that would make the gadolinium sufficiently soluble to be removed before the fissile material, enough of the completely insoluble hafnium would remain to prevent criticality.

5.8.4 PROBABILITY OF EXTERNAL CRITICALITY

Calculation of the probability of external criticality starts with the assumption that the waste package fails and liquid water has entered the waste package. Actually, there is a very low probability that any liquid water would enter a specific package; thus, the probability estimated here is very conservative. The probability of an external criticality event in either the repository or the rock beneath it is less than 4×10^{-12} in 10,000 years following repository closure. This low probability is primarily a result of the following Yucca Mountain characteristics: (1) limited dripping water to transport enough fissile material out of the waste package and into a geometry favorable for criticality; (2) a limited number of regions in the rock below the drifts to allow for fissile material accumulation in a geometry favorable for criticality; (3) a low concentration of fissile material in the water exiting out of a breached waste package due to low waste form solubility; and (4) lack of a chemical means to accumulate fissile materials and lack of a reducing environment to encourage precipitation.

5.8.5 EFFECT OF A STEADY-STATE CRITICALITY ON RADIONUCLIDE INVENTORY

If a steady-state criticality was to occur, it would be very unlikely to have a power level greater than 5 kilowatts. The power level would be limited because higher power, and thus higher temperatures, would evaporate the water that served as a moderator. An extremely conservative assumption would be that the criticality could endure for 10,000 years, which is the average period of a climate cycle that might have a high enough rainfall or drip rate to sustain the required level of water moderation against evaporation. For a typical commercial spent nuclear fuel waste package, a steady-state criticality would result in an increase of the inventory of certain radionuclides in that waste package. For the very conservative duration of 10,000 years, this increase would be less than 30 percent for the radionuclides in that package. The incremental impact of steady-state criticality events on the total inventory for the repository has been evaluated and is expected to be insignificant.

5.8.6 TRANSIENT CRITICALITY CONSEQUENCES

In the unlikely event that a transient criticality were to occur, a rapid initiating event could produce a peak power level of up to 10 megawatts for less than 60 seconds. After this brief period, rapid boiling of the water moderator would shut down the criticality. The short duration would limit the increase in radionuclide inventory to a factor of 100,000 smaller than that generated by the 10,000-year steady-state criticality. Other consequences of a transient criticality would be a peak temperature of 233ºC (451ºF) and a peak overpressure of 20 atmospheres. Both conditions would last 10 seconds or less and would not be expected to cause enough damage to the waste package or change its environment enough to have a significant impact on repository performance.

5.8.7 AUTOCATALYTIC CRITICALITY

When a criticality begins, there are several mechanisms that tend to shut it down. For example, the rapid evolution of heat and pressure can expand the fissile material, reducing its density and destroying the critical mass configuration. Evolution of steam can remove water moderator or decrease its effective density. In the case of autocatalytic criticality, there is such a high concentration of fissile material that there is an excess of critical mass and high rates of fission are achieved before any of the shutdown mechanisms occur. The result can be a “runaway” chain reaction, usually resulting in a steam explosion, or in the case of a nuclear bomb, a nuclear explosion. Contrary to popular belief, achieving such a configuration is extremely difficult and requires some very deliberate engineering. An autocatalytic criticality is not credible for the potential repository. Autocatalytic criticality is not possible at all for low-enriched waste forms, nor is it possible for the waste form inside the waste package. Even for highly enriched waste forms, or those containing nearly pure plutonium-239, achieving a critical mass outside a waste package would require the entire fissile content of the waste package to be spread uniformly in a nearly spherical shape, or it would require the extremely unlikely commingling of large amounts of transported fissile material from at least two waste packages containing highly enriched waste forms. Because the igneous rock at Yucca Mountain is unlikely to contain deposits that can efficiently accumulate fissile material, the probability of creating such a critical mass from a single or multiple waste packages containing highly enriched waste forms is so low as to be not credible.

5.8.8 DISRUPTIVE NATURAL EVENTS INFLUENCING CRITICALITY

The potential impact of disruptive natural events, such as seismic activity or igneous intrusion, on the risk of criticality in the repository has been studied. Seismic events could produce a rapid change in the configurations of waste forms and waste packages, potentially creating a critical configuration.

The potential adverse criticality considerations of igneous intrusion into the repository include: (1) the possibility of immediate waste package breach, (2) the separation of a significant fraction of the fissile material from the neutron absorber by magma transport, and (3) the accumulation of a critical mass of fissile material from, or within, the transporting magma. The potential for criticality following igneous intrusion has been evaluated for commercial spent nuclear fuel under extremely conservative assumptions, and no sufficiently probable mechanism for accumulating a critical mass has been identified.

5.9 Consequences to Biological Resources and Soils

DOE has considered whether the proposed repository would affect biological resources in the Yucca Mountain vicinity after closure through heating of the ground surface and through radiation exposure as the result of waste migration through groundwater to discharge points. No additional analyses for biological resources and soil have been performed for the design and operating mode changes made after the Draft EIS was published. The temperatures for the higher-temperature operating mode now being considered are bounded by the temperatures analyzed for the high-thermal load scenario in the Draft EIS and presented in this section.

After closure, heat from the radioactive decay of the waste could cause temperatures in the rock near the waste packages to rise above the boiling point of water at this altitude [96°C (205°F)] (DIRS 101779-DOE 1998, Volume 3, p. 3-36). The period the subsurface temperature could remain above the boiling point would vary from a few hundred years to a few thousand years, depending on the operating mode. Conduction and the flow of heated air and water through the rock (advection) would carry the heat from the waste packages through the rock to the surface and to the aquifer.

Although the atmosphere would remove excess heat when it reached the ground surface, the temperature of near-surface soils probably would increase slightly. Predicted increases in surface soil temperatures range from approximately 10°C (18°F) at the bedrock-soil interface (DIRS 100627-Bodvarsson and Bandurraga 1996, p. 510) to 6°C (10.8°F) for dry soil at a depth of 2 meters (6.6 feet) (Table 5-15). To address soil heterogeneity (differences in depth and water content), a recent study (DIRS 103618-CRWMS M&O 1999, all) modeled soil temperature increases at various depths under wet (saturated) and dry (no water at all) soil conditions for the high thermal load. They predicted that temperatures of near-surface soils would be unlikely to rise more than a few degrees (Table 5-14) but would increase with depth from the surface. Surface soil temperatures would start to increase approximately 200 years after repository closure and would peak more than 1,000 years after repository closure. Later, the temperature would gradually decline and would approximate prerepository conditions after 10,000 years (DIRS 103618-CRWMS M&O 1999, Figure 30 and p. 41).

Table 5-15. Predicted temperature changes of near-surface soils under the high thermal load scenario.[a,b]

Soil depth (meters)[c]	Predicted temperature increase [a]	
	Dry soil	Wet soil
0.5	1.5°C (2.7°F)	0.2°C (0.36°F)
1.0	3.0°C (5.4°F)	0.4°C (0.72°F)
2.0	6.0°C (10.8°F)	0.8°C (1.4°F)

a. Source: DIRS 103618-CRWMS M&O (1999, p. 38).
b. The high thermal load scenario was described and analyzed in the Draft EIS; this is not to be confused with the higher-temperature operating mode discussed in this Final EIS, which has a lower design heat loading.
c. To convert meters to inches, multiply by 39.37.

The maximum change in temperature would occur directly above the repository, affecting approximately 5 square kilometers (1,250 acres) under the higher-temperature operating mode. The effects of repository heat on the surface soil temperatures would gradually decline with distance from the repository (DIRS 103618-CRWMS M&O 1999, p. 43). Although not modeled, the increase in surface soil temperature would be lower under the lower-temperature operating mode, and the area that could be affected would be larger [as much as 6.2 square kilometers (1,550 acres) above the repository for the lower-temperature operating mode].

There is considerable uncertainty in the estimates of soil temperature increases due to uncertainties in the thermal properties of the soil at Yucca Mountain, particularly thermal conductivity (the amount of heat that can be conducted through a unit of soil per unit time) (DIRS 103618-CRWMS M&O 1999, p. 50). The predicted temperature increase for dry soil provides a conservative estimate of the temperature increase that could occur because even partially saturated soil has a much greater thermal conductivity than dry soil. Soil moisture content recorded at a depth of 15 centimeters (6 inches) was as low as 3 percent on some study sites during some months, but the soil was never completely dry (DIRS 105031-CRWMS M&O 1999, p. 14).

A depth of 1 meter (3.3 feet) is within the root zone for many desert shrubs. A temperature increase of 3°C (5.4°F) could affect root growth and other soil parameters such as the growth of microbes or nutrient availability. Studies at Yucca Mountain (DIRS 105031-CRWMS M&O 1999, pp. 11 to 46) show that due to natural variations some plant species experienced a spatial range in soil temperatures of 4°C (7.2°F) at a depth of 0.45 meter (18 inches), which is comparable to the 0.5-meter (20-inch) depth used by DIRS 103618-CRWMS M&O (1999, pp. 37-41). Impacts to biological resources probably would consist of an increase of heat-tolerant species over the repository and a decrease of less tolerant species. In general, areas affected by repository heating could experience a loss of shrub species and an increase in annual species. A gradual (over 1,000 years) temperature increase of the magnitude predicted (DIRS 103618-CRWMS M&O 1999, all) probably would have less effect on the plant community than a more rapid change.

The predicted increase in temperature would extend as far as 500 meters (1,600 feet) beyond the edge of the repository, with the greatest increase in temperature occurring in soils directly above the repository. A shift in the plant species composition, if any, would be limited to the area within 500 meters of the repository footprint [that is, as much as 8 square kilometers (2,000 acres)].

A shift in the plant community probably would lead to localized changes in the animal community that depends on it for food and shelter. Specific plant and animal species and community changes cannot be predicted with certainty because changes in climate or seasonal episodic events (droughts, high rainfall) can substantially change species responses to single factors. However, the variation in surface soil temperatures at Yucca Mountain that are caused by elevation, slope, aspect, and other natural attributes suggest that soil temperature increases of the magnitude predicted (DIRS 103618-CRWMS M&O 1999, pp. 44 to 48) are probably within the adaptive range of some plant species now at Yucca Mountain (DIRS 105031-CWRMS M&O 1999, pp. 11 to 46).

Some reptiles, including the desert tortoise, exhibit temperature-dependent sex determination (DIRS 103463-Spotila et al. 1994, all). Nest temperatures have a direct effect on sex determination, with low temperatures resulting in predominately male hatchlings and high temperatures resulting in predominately females. Although existing experimental data do not adequately represent the large fluctuations in nest temperatures in natural settings, an increase in soil temperature due to repository operations could influence the sex ratio and other aspects of the life history of the desert tortoise population residing over the repository footprint. However, depth to the top eggs of 23 nests at Yucca Mountain during 1994 averaged 11 centimeters (4.3 inches). Predicted temperature increases of clutches at that depth based on modeling results (DIRS 103618-CRWMS M&O 1999, pp. 37 to 42) would be less than 0.5ºC (0.9°F). Given the ranges of critical temperatures reported by DIRS 103463-Spotila et al. (1994, all), an increase of this magnitude would be unlikely to cause adverse effects.

Changes in plant nutrient uptake, growth, and species composition, as a result of increases in soil temperature over long periods of time, could influence vegetation community dynamics and possibly alter desert tortoise habitat structure in areas immediately above the repository. However, little is known about the effects that minor alterations in habitat would have on desert tortoise population dynamics.

As discussed in Sections 5.4 and 5.6, in the distant future water at certain discharge points would be likely to carry concentrations of radionuclides and chemically toxic substances. DOE did not quantify impacts to biological resources from irrigation water extracted at the RMEI location, from irrigation water extracted at 30 kilometers (19 miles) downgradient from the potential repository, or for the evaporation of water at Franklin Lake Playa (where there is no surface water at present). The estimated doses to humans exposed to this water would be very small. Expected dose rates to plants and animals would be much less than 100 millirad per day. The International Atomic Energy Agency concluded that chronic dose rates less than 100 millirad per day are unlikely to cause measurable detrimental effects in populations of the more radiosensitive species in terrestrial ecosystems (DIRS 103277-IAEA 1992, p. 53).

The desert tortoise is the only threatened or endangered species in the analyzed repository land withdrawal area (DIRS 104593-CRWMS M&O 1999, p. 3-14). Desert tortoises are rare or absent on or around playas (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411; DIRS 103160-Bury and Germano 1994, pp. 64 and 65); therefore, DOE anticipates no impacts to this species from contaminated water resources at Franklin Lake Playa in the future.

Impacts to surface soils would be possible. Changes in the plant community as a result of the presence of the repository could lead to an increase in the amount of rainfall runoff and, therefore, an increase in the erosion of surface soils, thereby increasing the sediment load in ephemeral surface water in the immediate Yucca Mountain vicinity.

5.10 Summary

Potential long-term impacts to human health from a repository at Yucca Mountain would be dominated by impacts from radioactive materials in the waterborne pathway under the Proposed Action. Although future disruptive events (human intrusion, volcanic activity, seismic activity) would change radiation exposure rates, the effect of these on the reported impacts for the nominal scenario would be small.

Tables 5-6 and 5-10 list individual doses from groundwater releases of radionuclides during 10,000 years after repository closure. The mean annual individual doses at the RMEI location are summarized in Table 5-16. The mean annual individual doses in Table 5-16 are much less than the limit of 15 millirem in 40 CFR Part 197.

Table 5-16. Individual impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the Proposed Action.[a]

Operating mode	Peak mean annual individual dose at the RMEI location (millirem)[b]	Peak mean annual probability of an LCF[c]
Higher-temperature	0.00002	6×10^{-10}
Lower-temperature	0.00001	4×10^{-10}

a. Values based on the mean peak-dose rates from 300 simulations of total system performance using random samples of uncertain parameters.
b. The RMEI location is approximately 18 kilometers (11 miles) downgradient from the potential repository.
c. LCF = latent cancer fatality.

Tables 5-7 and 5-11 list estimated lifetime and 10,000-year integrated radiation dose impacts for members of the affected population from the groundwater release pathway during the first 10,000 years after repository closure. Table 5-17 summarizes the health effects for the affected population of 74,000 persons based on a 10,000-year integrated basis.

The average mortality rate for cancer deaths per 100,000 persons in Nevada is 202 (DIRS 153066-Murphy 2000, p. 83). Using the Nevada cancer death rate, about 154 cancer fatalities would normally occur each year in the population affected by groundwater potentially contaminated by a repository at Yucca Mountain (74,000 persons). All of the values in Table 5-17 are much smaller than 1, meaning that it is most likely than no person would die due to groundwater contamination by radiological material in the 10,000-year period after repository closure. This comparison clearly indicates that human health impacts associated with effects on groundwater from the Proposed Action would be very small for the affected population. Using the Nevada cancer death rate, about 140 cancer fatalities would normally occur each year in the population within an 80-kilometer radius of Yucca Mountain (assuming a population of about 76,000 persons). All of the values in Table 5-17 are much smaller than 1.0, meaning that it is most likely that no person would die due to groundwater contamination by radiological material in the 10,000-year period after repository closure. This comparison clearly indicates that human health impacts associated with the Proposed Action would be very small for the population in general.

Table 5-17. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the Proposed Action.[a]

Operating mode	Peak annual LCFs[b]	10,000-year integrated LCFs
Higher-temperature	0.000003	0.0002
Lower-temperature	0.000002	0.0002

a. Values based on the mean peak-dose rates from 300 simulations of total system performance using random samples of uncertain parameters.
b. LCFs = latent cancer fatalities.

The analysis indicates (as listed in Table 5-17 and the peak dose values) that there is no significant difference in impacts due to the operating mode, even though the impacts for the higher-temperature mode appear to be slightly larger than those impacts for the lower-temperature mode. One reason for the similarity in annual individual dose between the operating modes is that most waste packages would still be intact beyond the time at which the repository temperature would be elevated much above ambient rock temperatures (DIRS 155950-BSC 2001, p. 7-85). Thus, most radionuclides would not be released until long after the thermal effects had subsided and, therefore, the operating modes would not have a large effect on the peak doses.

The EPA has set annual dose limits of 15 millirem to an individual for human intrusion and igneous disruption events (40 CFR Part 197). As shown in Figure 5-7, the peak of the mean annual dose rate from a human intrusion 30,000 years after repository closure would be 0.002 millirem. The probability weighted mean annual dose to an individual for the igneous intrusion scenario would have a peak of 0.1 millirem. Both of these results are well below the regulatory limits.

The peak mean annual individual doses at the RMEI location in the first 1 million years after repository closure would be 150 millirem for the higher-temperature operating mode and 120 millirem for the lower-temperature operating mode. These doses do not specifically include the effects of disruptive events. The effects of disruptive events would be very small compared to the 1-million-year peak annual dose. These effects are evaluated separately and reported in Section 5.7.

As listed in Table 5-14, human impacts from chemically toxic materials would be unlikely because water concentrations would be below Maximum Contaminant Level Goals (40 CFR 191.51) or Oral Reference Doses (chromium, DIRS 148224-EPA 1999, all; molybdenum, DIRS 148228-EPA 1999, all; nickel, DIRS 148229-EPA 1999, all; and vanadium, DIRS 103705-EPA 1997, all). Estimated concentrations of radionuclides in groundwater (see Table 5-9) would be hundreds of thousands of times less than regulatory limits (40 CFR 197.30). Atmospheric release of carbon-14 would yield an estimated 80-kilometer (50-mile) population impact of 5.3×10^{-10} latent cancer fatality during the 70-year period of maximum release, much lower than the groundwater-borne population impacts. Finally, as discussed in Section 5.9, there are no anticipated adverse impacts to biological resources from either repository heating effects or the migration of radioactive materials.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

104328	ASTM 1998	ASTM (American Society for Testing and Materials). 1998. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip.* B 575-97. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816.
100627	Bodvarsson and Bandurraga 1996	Bodvarsson, G.S. and Bandurraga, T.M., eds. 1996. *Development and Calibration of the Three-Dimensional Site-Scale Unsaturated Zone Model of Yucca Mountain, Nevada.* Berkeley, California: Lawrence Berkeley National Laboratory. ACC: MOL.19970211.0176.
152059	BSC 2001	BSC (Bechtel SAIC Company) 2001. *Performance Assessment of U.S. Department of Energy Spent Fuels in Support of Site Recommendation.* CAL-WIS-PA-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010627.0026.
154554	BSC 2001	BSC (Bechtel SAIC Company) 2001. *Lower-Temperature Subsurface Layout and Ventilation Concepts.* ANL-WER-MD-000002 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010718.0225.
154659	BSC 2001	BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.
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6. ENVIRONMENTAL IMPACTS OF TRANSPORTATION

This chapter describes the potential environmental consequences of transporting the spent nuclear fuel and high-level radioactive waste described in Chapter 2 and Appendix A from 72 commercial and 5 U.S. Department of Energy (DOE, or the Department) sites to the Yucca Mountain site under the Proposed Action. This chapter also separately describes the potential impacts of transportation activities in the State of Nevada.

On a national basis DOE analyzed impacts of transporting spent nuclear fuel, including potential commercial spent mixed-oxide fuel containing surplus plutonium that originated from U.S. defense programs, and high-level radioactive waste, including high-level radioactive waste that could contain immobilized surplus plutonium from U.S. defense programs. These impacts include all activities necessary to transport these materials, from loading at the commercial and DOE facilities to delivery at the Yucca Mountain site. In addition, although DOE would prefer that most shipments be carried out by rail, the analysis addressed two scenarios—*mostly legal-weight truck* and *mostly rail*. These two scenarios allowed the analysis to encompass the range of potential impacts for any mix of truck and rail shipments that would actually occur. Because naval spent nuclear fuel would not be shipped by legal-weight truck (DIRS 101941-USN 1996, all) and not all of the generator sites can handle rail casks, the national scenarios involve the use of mostly legal-weight truck shipments (with only naval spent nuclear fuel being transported by rail) or mostly rail shipments (with transportation of some commercial spent nuclear fuel by truck). In addition, as part of the mostly rail scenario, the analysis assessed impacts of short hauls of commercial spent nuclear fuel in heavy-haul trucks or barges from some commercial sites to nearby railheads.

For the discussion of potential impacts of transportation by truck or rail in Nevada, such impacts would be a subset of the impacts of potential national impacts. They are discussed separately so they can be compared to a third mode of transportation, the use of heavy-haul trucks, for spent nuclear fuel and high-level radioactive waste that would arrive in Nevada by rail. Thus, the analysis considered three alternative modes of transportation for shipments once they would arrive in Nevada: (1) for those arriving by legal-weight truck, continuing the shipments by legal-weight truck to the Yucca Mountain site; (2) for those arriving by train, continuing the shipments by rail using a branch rail line in one of five candidate rail corridors to the site; or (3) for those arriving by rail, unloading the shipments from railcars and loading them on heavy-haul trucks at an intermodal transfer station for shipment to the site on one of five candidate highway routes. Figure 6-1 shows these three options. The candidate highway routes for heavy-haul trucks and rail corridors for a potential branch rail line are called *implementing alternatives*. Figure 6-2 shows the transportation implementing alternatives and their relationships to the national and Nevada transportation scenarios and to the mix of rail and legal-weight truck transportation modes that make up each scenario.

Section 6.1 summarizes both national and Nevada transportation activities. Chapter 2, Section 2.1.3, also describes national and Nevada transportation activities. Section 6.2 assesses the potential impacts of national transportation from the 77 sites to Yucca Mountain. Section 6.3 assesses potential impacts from transportation activities in Nevada. Chapter 2 describes the receipt and unloading of shipping casks at the repository (Section 2.1.2.1.1.1), the preparation of empty casks for reshipment (Section 2.1.2.1.1.3), and the potential construction and operation of a cask maintenance facility (Section 2.1.3.4). Chapter 4, Section 4.1.15, evaluates potential environmental impacts from the offsite manufacturing of shipping casks for commercial spent nuclear fuel and DOE spent nuclear fuel and high-level radioactive waste. Chapter 8, Section 8.4, discusses cumulative impacts of transportation for the Proposed Action and anticipated future radioactive material transportation activities. Appendix J contains details on transportation analysis methods and results. Appendix M provides information that is not needed to evaluate environmental impacts but that could be useful to readers to gain an understanding of nuclear waste transportation.

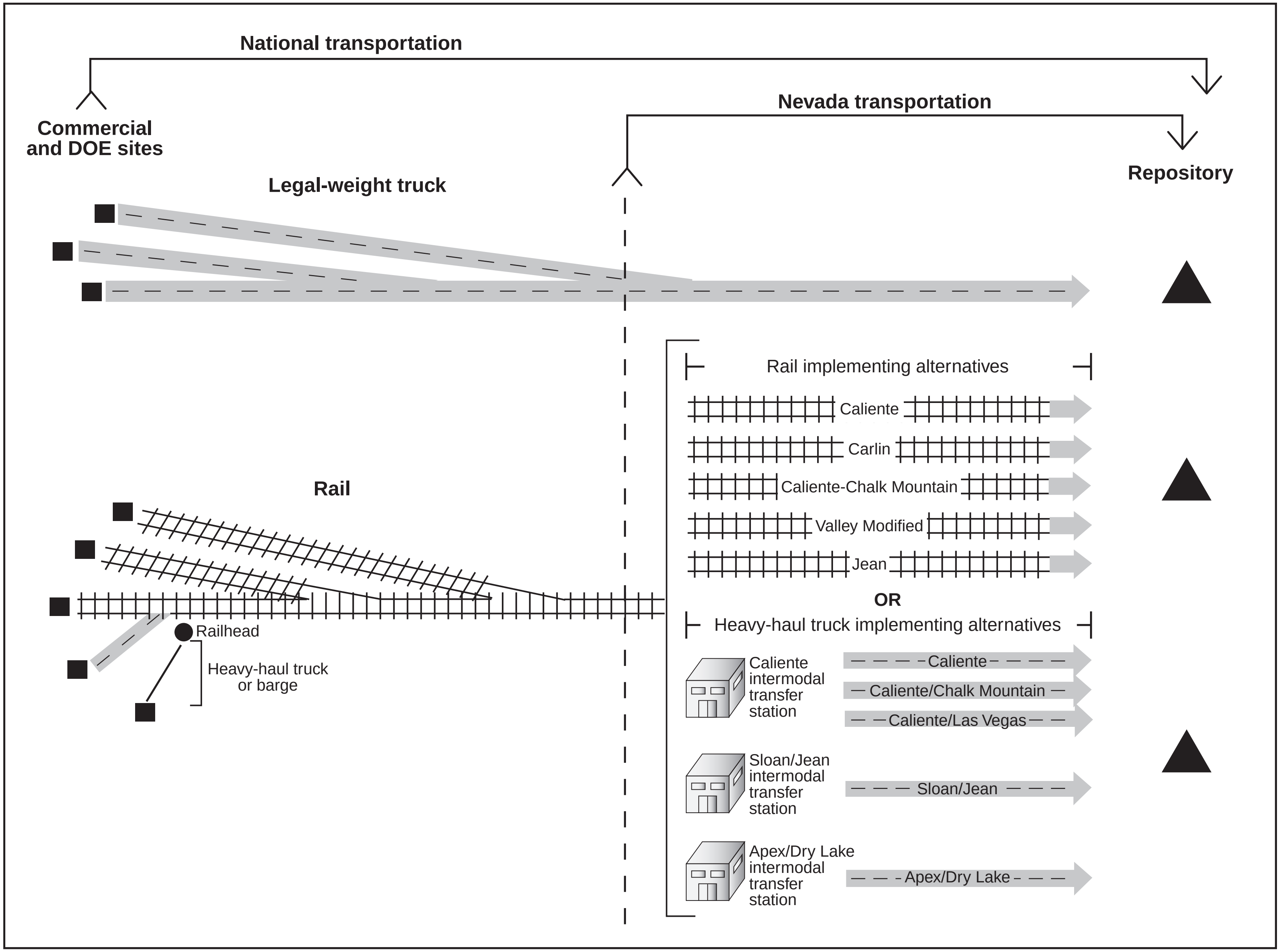
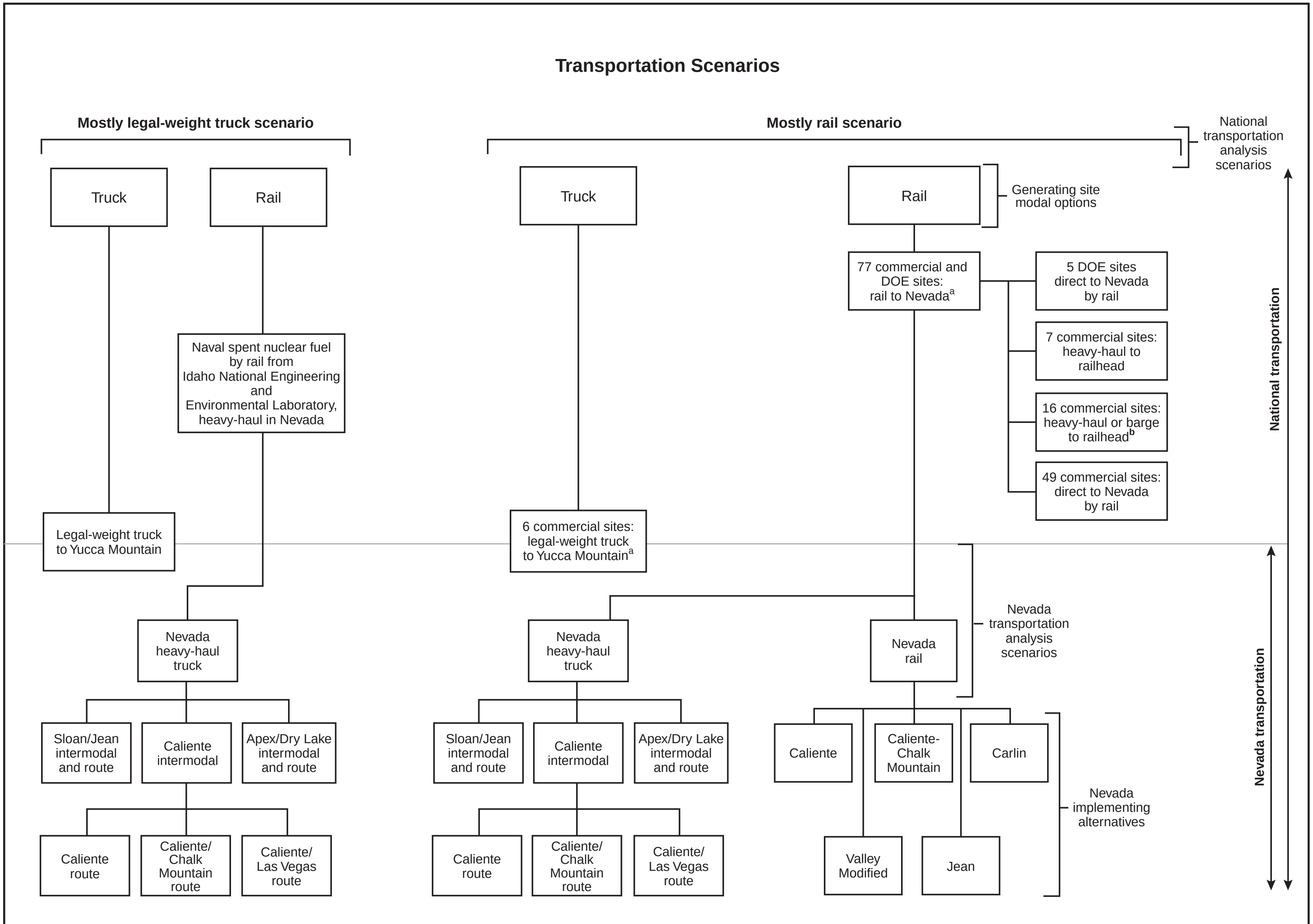


Figure 6-1. Relationship of Nevada and national transportation.



a. Six commercial sites would not have rail access until after reactor shutdown.
b. Salem and Hope Creek listed as one site.

Figure 6-2. Relationship between transportation modes, national and Nevada analytical scenarios, and Nevada transportation implementing alternatives.

CHANGES SINCE THE PUBLICATION OF THE DRAFT EIS

Changes in Information, Analytic Tools, and Assumptions

Since the publication of the Draft EIS, DOE has acquired new information and analytic tools that contribute to an improved understanding of interactions between the potentially affected environment and transportation activities necessary for the Proposed Action, including information and suggestions for improvements provided in public comments on the Draft EIS and on the Supplement to the Draft EIS. As a consequence, the impacts described in this chapter, Appendix J, and other transportation-related sections of this Final EIS differ from those described in the Draft EIS.

Notably, estimates of total impacts to public health and safety described in this chapter are smaller than those in the Draft EIS. With the exception of consequences of postulated acts of sabotage, estimates for radiological impacts of *incident-free transportation* and accidents and consequences of maximum reasonably foreseeable accidents are all smaller than the estimates in the Draft EIS. The nonradiological impacts reported in this Final EIS are approximately the same as those in the Draft EIS, including those in the Supplement to the Draft EIS. Differences in estimates of transportation-related impacts for land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; waste management; utilities, energy, and materials; and environmental justice are principally the result of new information that enabled better representation of impacts that were, for the most part, identified in the Draft EIS and, for land use, changes in the affected environment that occurred after the publication of the Draft EIS. The following paragraphs describe the changes that had the most effect on the impact results, including comparisons with the results presented in the Draft EIS.

Estimated Numbers of Shipments. Estimates of the number of shipments of commercial spent nuclear fuel that would be made under the mostly legal-weight truck and mostly rail scenarios were based on a version of the CALVIN computer program (DIRS 155644-CRWMS M&O 1999, all) that has been updated from the version used for the Draft EIS. The updated version of CALVIN (Version 2.0) incorporates a number of changes, including: (1) revised estimates of future generation of commercial spent nuclear fuel; (2) revised estimates of the capabilities of commercial generator sites to handle and load large shipping casks; (3) revised estimates of the types and sizes of shipping casks that would be used; and (4) revised assumptions about how sites would select spent nuclear fuel assemblies for delivery to DOE.

The Final EIS analyses used a total of about 53,000 legal-weight truck shipments and 300 rail shipments of naval spent nuclear fuel for the mostly legal-weight truck scenario. This is an increase of about 3,000 shipments or 6 percent over the approximately 50,000 shipments reported in the Draft EIS. This increase is the result of slight changes in the assumed characteristics of spent nuclear fuel that commercial generators would deliver to DOE.

For the mostly rail scenario, the total number of shipments in the Final EIS analyses is about 10,700. About 1,100 of these shipments would be by legal-weight truck. The Draft EIS used a total of about 13,400 shipments (about 25 percent more), of which about 10,800 would be by rail and 2,600 by legal-weight truck. The reduced number of shipments is a result of changes in assumptions regarding the size of shipping casks and the capabilities of generator sites to handle and load rail casks. For this scenario, based on information available from industry sources following the publication of the Draft EIS, the updated CALVIN analysis assumed three generator sites previously considered capable of handling and loading only legal-weight truck casks could handle and load rail casks. In addition, the analysis assumed that the remaining truck-only sites would be capable of handling and loading rail casks following permanent shutdown of the sites' reactors.

Based solely on changes in the number of shipments, estimates of health and safety impacts nationally and in Nevada are 6 percent greater for the mostly legal-weight truck scenario and about 25 percent less for the mostly rail scenario than those reported in the Draft EIS. The change in the number of shipments would not cause discernible changes in impacts in other resource areas discussed in this chapter.

Characteristics of Commercial Spent Nuclear Fuel Used in Accident Analyses. The transportation analysis used the characteristics of representative spent nuclear fuel described in Appendix A, rather than the characteristics of typical (or average age) spent nuclear fuel used in the Draft EIS, to evaluate potential impacts and consequences of transportation accidents. Representative spent nuclear fuel is commercial spent nuclear fuel with a health and safety hazard that is the average of all the spent nuclear fuel that would be shipped to the proposed repository. Under this averaging, representative spent nuclear fuel would be (1) spent nuclear fuel from a pressurized-water reactor that had been discharged from a reactor for 15 years and had an average burnup of 50,000 megawatt-days per metric ton of heavy metal (MTHM), or (2) spent nuclear fuel from a boiling-water reactor that had been discharged for 14 years with a burnup of 40,000 megawatt-days per MTHM. Conversely, typical pressurized-water reactor spent nuclear fuel (also described in Appendix A) has been discharged from a reactor for 25.9 years with a burnup of almost 40,000 megawatt-days per MTHM. Typical boiling-water reactor spent nuclear fuel has been discharged from a reactor for 27.2 years with a burnup of about 32,000 megawatt-days per MTHM. DOE made the change to a representative fuel for accident analysis because it determined that estimates of accident risk using the characteristics of the typical spent nuclear fuel discussed in the Draft EIS underestimated the accident risk of shipments. This change in the analysis resulted in about a twofold increase in the estimated inventory of primary radionuclides in each shipping cask in comparison to the estimates in the Draft EIS. Primary radionuclides are those that contribute the most to impacts (see Appendix J, Section J.1.3.1).

Highway and Rail Routes. The analyses of transportation impacts in the Draft and Final EIS used the HIGHWAY (DIRS 104780-Johnson et al. 1993, all) and INTERLINE (DIRS 104781-Johnson et al. 1993, all) computer programs to identify routes that DOE could use for shipments from 77 generator sites to a Yucca Mountain Repository. DOE believes that the identified routes are representative of those that would be used if the Yucca Mountain site was approved and a repository was constructed and operated.

IDENTIFICATION OF TRANSPORTATION ROUTES

DOE has published proposed policy and procedures (63 *FR* 23756; April 30, 1998) "setting forth its revised plans for implementing a program of technical and financial assistance to states for training public safety officials of appropriate units of local government and to Indian tribes through whose jurisdictions the Department plans to transport spent nuclear fuel or high-level radioactive waste." The proposed policy and procedures state that DOE "plans to identify preliminary routes [that the Department] anticipates using within state and tribal jurisdictions when it notifies governors and tribal leaders of their eligibility." Notification would begin "approximately five years prior to transportation through" affected jurisdictions.

Most of the routes used for analyses in the Final EIS did not change from those used for the Draft EIS. However, railroad consolidations and alternative preferred routes designated by states for highway shipments resulted in changes in some of the routes identified by the computer programs and used in the analyses. For example, railroad consolidation led to a change in a potential *rail route* from the Monticello generator site in Minnesota. This caused the State of South Dakota, which was not included among the states crossed by routes analyzed in the Draft EIS, to become one of the states through which the analysis assumed shipments would travel.

In the case of highway shipments, new information published by the U.S. Department of Transportation (65 *FR* 75771; December 4, 2000) lists 14 states that have designated preferred routes for truck shipments of Highway Route-Controlled Quantities of Radioactive Materials. The Draft EIS listed 10 states based on information available at the time. The four added states are Delaware, Ohio, Texas, and Utah. Also listed for the first time in an integrated source are route restrictions and preferred route designations made by the State of Colorado that would preclude the use of Interstate Highway 70 west of Denver to the Utah border. The new information resulted in changes in the routing that the Draft EIS analysis assumed for some shipments.

Overall, the effects of changes in the routes used in the analysis on estimated impacts would be small for national transportation. However, DOE has added maps and tables that show the routes that were analyzed and the estimated health and safety impacts for each state through which shipments would pass if these routes were used (Appendix J, Section J.4).

Bureau of the Census Data. The analyses in the Draft and Final EIS used the HIGHWAY and INTERLINE computer programs to develop estimates of potentially affected populations along transportation routes. These programs use block group data from the 1990 Census. The Draft EIS used estimates of population along routes provided by these programs to estimate radiological impacts of transportation nationally and in Nevada. In a change from the Draft EIS, the Final EIS analysis used projections for each state made by the Bureau of the Census for population growth to 2025, results of the 2000 Census, and extrapolation to estimate populations along routes in 2035. These estimated population increases were used in estimating radiological health and safety impacts for national transportation.

In another change, estimates of populations along potential routes in the State of Nevada incorporate information developed using a geographic information system, 1990 Census data, and projections to 2035 obtained using the REMI computer program. Projections using REMI were based on forecasts provided to DOE by Clark County, Nye County, and the Nevada State Demographer, anchored to the results of the 2000 Census for Nevada counties. In addition, population estimates for routes that include the planned Las Vegas Beltway used a forecast for 2020 provided by a report prepared for the City of North Las Vegas (DIRS 155112-Berger 2000, all).

The overall effect of these changes is that estimated affected populations along national routes would be about 40 percent greater than the populations estimated with the use of 1990 Census data, as used in the Draft EIS. The Nevada population used in the analysis of transportation-related health and safety impacts in this Final EIS is about 100 percent greater than that used in the Draft EIS.

DOE conducted a limited sensitivity analysis of national transportation impacts using route population information based on projections provided by the TRAGIS computer program (DIRS 157136-Johnson and Michelhaugh 2000, all). The TRAGIS program, which DOE released in the Fall of 2001 to replace the HIGHWAY and INTERLINE computer codes used for the transportation analyses in this EIS, uses 2000 Census data to develop population estimates for routes. Based on the sensitivity analysis performed using TRAGIS in place of HIGHWAY, DOE determined that doses to the general public from incident-free transportation would be similar to (about 10 percent greater than) those reported in this chapter.

Performance of Shipping Casks in Transportation Accidents. DOE has revised the transportation accident analyses in the EIS to reflect new information. For example, since the publication of the Draft EIS, the Nuclear Regulatory Commission published *Reexamination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all). Based on the analyses in that report, DOE concluded that the models used for analysis in the Draft EIS relied on assumptions about spent nuclear fuel and cask response to accident conditions that caused an overestimation of the resulting impacts. For example, the analyses in the Draft EIS were based on *Shipping Container Response to Severe Highway and Railway*

***Assessment of the Hazards of Transporting Spent Nuclear Fuel and High-Level Radioactive Waste to the Proposed Yucca Mountain Repository Using the Proposed Northern Las Vegas Beltway* (DIRS 155112-Berger 2000, all)**

The transportation analyses in the Final EIS used some information from this document. DOE considers this report to be the only available source of some information, but is in broad disagreement with the analyses and conclusions regarding the report's estimates of impacts.

Useful information not available elsewhere includes:

- An estimate of population along the Las Vegas Beltway—an area that is currently mostly uninhabited—although, as discussed below, DOE believes the estimate is high.
- New information regarding the expected cost to construct the beltway.
- A scenario for estimating dose to a maximally exposed individual along a highway route used by heavy-haul trucks in Nevada.

DOE disagrees with some aspects of the report for a variety of reasons, including:

- The projected population growth within 3.2 kilometers (2 miles) of the 21-kilometer (13-mile)-long Northern Beltway appears to be very high, accounting for 42 percent of population growth projected by a University of Nevada Las Vegas report (DIRS 156031-Riddel and Schwer 2000, Table 1) for all of Clark County during the same period.
- The report uses a very high accident rate as a basis for accident probabilities. This rate—4 times that reported to DOE by the State of Nevada for interstate trucks on all Nevada highways (see Appendix J, Section J.1.4.2.3.3)—is 17 times greater than the rate DOE used in the EIS, which is based on statistics compiled by the U.S. Department of Transportation. The rate could be higher in part because it was based on the State of Nevada definition of an accident rather than the Department of Transportation definition recommended by the National Governors Association (see Sections J.1.4.2.3 and J.1.4.2.3.3). In addition, the rate used in the report appears to be an intercity rate (urban interstate) that does not accurately reflect the accident rate for highways in Nevada that shipments to Yucca Mountain would use.
- The report projects economic impacts in the Northern Beltway area assuming that business location decisions would be made solely on whether shipments of spent nuclear fuel and high-level radioactive waste would use the Northern Beltway. The report did not consider many other factors commonly associated with such decisions.
- The report overestimates economic impacts to Clark County under the implied assumption that not only would some companies not locate near the Northern Beltway because of shipments of spent nuclear fuel and high-level radioactive waste, these companies would not locate anywhere in Clark County; and that existing Clark County companies that could move to the Northern Beltway area would actually leave Clark County. The report ignores statistics that show that many business relocations occur in the same county. In addition, the report fails to recognize that decisions to remain at the same location would have no economic impact on the county.

Accident Conditions, which estimated that 99.4 percent of accidents would not lead to a release of radioactive materials from a shipping cask (DIRS 101828-Fischer et al. 1987, pp. 4-8, 7-25, and 7-26). Based on the revised analyses, casks would continue to contain spent nuclear fuel fully in more than 99.99 percent of all accidents (DIRS 152476-Sprung et al. 2000, p. 7-73 to 7-76). In addition, based on that report, DOE has included impacts of an accident in which the radiation shielding of a shipping cask would be damaged—so-called *loss-of-shielding* accidents. DOE also included estimated impacts of 99.99 percent of accidents in which the cask's containment and shielding would not be damaged by the accident but where nearby populations could be exposed to low-level radiation during the time it would take for accident response and recovery. The analysis assumed the low-level radiation would be the maximum allowed by regulation for a cask transporting spent nuclear fuel or high-level radioactive waste. The Draft EIS did not include these evaluations.

The collective effect of these changes was a significant reduction in estimated consequences of maximum reasonably foreseeable accidents and estimates of accident risk from those presented in the Draft EIS. In addition, the use of information from the DIRS 152476-Sprung et al. (2000, all) report permits a better description of the maximum reasonably foreseeable accidents analyzed. For example, the characteristics of the maximum reasonably foreseeable accident analyzed in this chapter for rail transportation correspond closely to reported conditions in the Baltimore Tunnel train accident fire in July 2001 (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all).

Model for Estimating Doses to the Public at Truck Stops. The Draft EIS used information reported in DIRS 101888-Neuhauser and Kanipe (1992, p. 3-29) to estimate the radiation dose that would be received by members of the public at rest stops used by trucks carrying spent nuclear fuel and high-level radioactive waste. The time allocated to stops in the report is equivalent to about 1 hour of stop per hour of travel—a significant overestimate of stop time in real truck transport operations involving team drivers. As a consequence, more than 90 percent of the dose to the general public reported for the mostly legal-weight truck scenario in the Draft EIS was based on this estimate of dose to persons at truck stops.

The analysis in this Final EIS used more recent data based on field observations of truck stop time (DIRS 152084-Griego, Smith, and Neuhauser 1996, all). In addition, the analysis estimated doses to populations in areas surrounding stops, including estimates of stop time for state inspections and periodic driver walk-around, which were not part of the analyses in the Draft EIS. The analysis concluded that the average time trucks would stop would be about 1 hour for every 10 hours of travel, which resulted in a much lower estimate for radiation dose to the general public. Appendix J, Section J.1.3.2.1 provides additional information.

RADTRAN. DOE used the RADTRAN 4 computer program in estimating the radiological incident-free and accident risk impacts in the Draft EIS. For this Final EIS, DOE used an updated version of the program, RADTRAN 5, which allowed more complex analyses of impacts, such as those involving models used to estimate doses to persons at truck stops. With the exception of the improvements in capabilities afforded by RADTRAN 5, the analytical methods used by the two programs to estimate impacts to populations are largely the same. This change had no effect on the results.

Health Effect Fatality Impacts of Vehicle Emissions. New information used to estimate fatalities from health effects of vehicle emissions (DIRS 151198-Biwer and Butler 1999, all) became available following the publication of the Draft EIS. DOE used this information in conjunction with information from the Environmental Protection Agency (DIRS 155780-EPA 1993, all; DIRS 155786-EPA 1997, all) to develop risk factors for the analysis in this Final EIS. Based on this new data, estimates of impacts from vehicle emissions are about 3 times greater than the estimates in the Draft EIS, which ranged from 0.2 to 0.6 fatalities over 24 years.

First Responder. The analyses of transportation impacts in this Final EIS included estimates of doses to maximally exposed individuals not identified in the Draft EIS. These included estimates of doses to a first responder at a transportation accident and individuals who resided close to highways or rail routes in the State of Nevada.

Socioeconomic Baseline for Nevada Counties. The analyses of socioeconomic impacts in the Draft and Final EIS used baseline data developed using the REMI computer program. However, input parameters to calculations performed using REMI were adjusted for the Final EIS so predicted results reflect similar forecasts provided by Clark and Nye Counties and the Nevada State Demographer. The resultant changes in estimated socioeconomic impacts are small.

Time to Construct a Branch Rail Line. After the publication of the Draft EIS, the estimated time to construct a branch rail line to the Yucca Mountain site changed from 2.5 years (30 months) to 40 to 46 months, depending on the corridor. However, engineering estimates of materials and labor required for construction did not change, and therefore the constant-dollar cost estimates did not change. The changes in projected construction schedules led to lower estimates for socioeconomic impacts of constructing and operating a branch rail line in Nevada than those in the Draft EIS.

Cost to Construct the Las Vegas Beltway. The EIS includes estimates of socioeconomic impacts of using heavy-haul trucks on three candidate routes that include the planned Las Vegas Beltway. The analysis in the Draft EIS assumed an expenditure of $40 million (1998 dollars) for the northern segment of the Beltway, occurring between 2007 and 2010 rather than between 2010 and 2020 as planned by Clark County. The Draft EIS analysis also assumed a corresponding total of $90 million (1998 dollars) for the southern and western segments of the Beltway. An estimate in a City of North Las Vegas-sponsored report suggests the cost of completing the Northern Beltway between 2010 and 2020 could be as much as $425 million in 1998 dollars (DIRS 155112-Berger 2000, p. 29) ($463 million in 2001 dollars). DOE adopted this estimate for use in estimating socioeconomic impacts for the Caliente/Las Vegas and Apex/Dry Lake routes for heavy-haul trucks evaluated in this chapter. Using the same information, the analysis in this chapter estimated socioeconomic impacts for a Jean route for heavy-haul trucks with the assumption that the corresponding costs to complete the southern and western segments of the Beltway could be as much as $790 million. Because it assumed these larger estimated costs, the estimated socioeconomic impacts in Clark County for the Jean, Apex/Dry Lake, and Caliente/Las Vegas routes for heavy-haul trucks are higher in this Final EIS than those in the Draft EIS, but remain low for the County.

Potential Land-Use Conflicts for Construction and Operation of a Branch Rail Line in Nevada. After the publication of the Draft EIS, changes occurred in ownership and use of lands that a branch rail line in the candidate rail corridors in Nevada could cross. Land that could be crossed by the Bonnie Claire Alternate of the Caliente and Carlin Corridors has been transferred by an Act of Congress to the Timbisha Shoshone Tribe; land at the junction of the Stateline Pass Option of the Jean Corridor and the Union Pacific Railroad has been transferred by an Act of Congress to Clark County for development of the Ivanpah Valley Airport; and land near the junction of the Valley Modified Corridor and the Union Pacific Railroad has been transferred by the Bureau of Land Management to Clark County for the Apex Industrial Park. These changes result in potential land-use impacts for the affected corridors.

Changes Due to Public Comments. In response to interest and suggestions by the public and to better describe potential impacts of transportation alternatives in Nevada, DOE has modified analyses and presentations of impacts. The following are examples of such modifications:

- *Land-use and ownership.* Added available descriptive details and assessed potential impacts to wilderness study areas; grazing allotments; rights-of-way; and Bureau of Land Management, private, Nellis Air Force Range (now called the Nevada Test and Training Range), Native American, and Nevada Test Site lands along Nevada rail corridors, including variations, and along routes for heavy-haul trucks.

- *Air quality (nonradiological).* Provided more complete quantitative estimates of carbon monoxide and PM_{10} emissions from transportation activities, particularly in the Las Vegas Valley nonattainment area.

- *Hydrologic resources.* Expanded flood zone, groundwater, and surface-water resources, and water demand analyses to incorporate information for variations of Nevada rail corridors and for routes for heavy-haul trucks.

- *Biological resources and soils.* Provided more details from existing information and analyses of disturbed areas, sensitive biological resources, management areas, and soil impacts.

- *Cultural resources.* Acquired and evaluated additional cultural, archeological, and Native American data and included evaluations of potential impacts of Nevada rail variations and heavy-haul truck routes.

- *Socioeconomics.* Updated socioeconomic baseline information to accommodate 2000 Census information as well as match population forecasts provided by Clark and Nye Counties and Nevada State Demographer.

- *Noise and vibration.* Added new data and developed additional analyses of impacts of ground vibration and noise on *sensitive structures*, populations, and communities along Nevada rail corridors and routes for heavy-haul trucks.

- *Aesthetics.* Incorporated field observations made after the publication of the Draft EIS for viewsheds along candidate rail corridors and routes for heavy-haul trucks and used additional detail available from existing information.

- *Environmental justice.* Added available detail, reanalyzed data on minority and low-income populations, and reevaluated impact assessments of other disciplines.

- *Utilities, energy, and materials.* Reanalyzed impacts based on new information for the repository flexible design and for variations in the candidate rail corridors.

- *Waste management.* Added new waste data, details of waste sources and shipments, and changes in waste management from changes in information regarding the repository flexible design.

Other Changes

In addition to the changes described above, DOE added Appendix M to provide general background information on transportation-related topics that are not addressed in detail in this chapter or Appendix J and are not directly related to potential impacts of the Proposed Action. This includes information on the Department's planning, under a draft Request for Proposal, to issue shipping contracts and discussion of in-transit procedures, emergency response plans, indemnification against damages from the potential release of spent nuclear fuel and high-level waste, and cask testing.

6.1 Summary of Impacts of Transportation

6.1.1 Overview of National Transportation Impacts

This section provides an overview of the potential impacts of using the Nation's highways and railroads to transport spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites to the repository at Yucca Mountain. Detailed discussions of national transportation impacts are in Section 6.2 and analytical methods are in Appendix J. All potential impacts are related to the health and safety of populations and hypothetical maximally exposed individual members of the general public and workers. This summary includes estimated impacts from loading operations, incident-free transportation, and

- *Hydrologic resources.* Expanded flood zone, groundwater, and surface-water resources, and water demand analyses to incorporate information for variations of Nevada rail corridors and for routes for heavy-haul trucks.

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Estimated national transportation impacts are based on 24 years of transportation activities during the Proposed Action and average annual shipments of about 2,200 (2,200 truck, 13 rail) for the mostly legal-weight truck scenario and about 450 (400 rail, 45 truck) for the mostly rail scenario. From all causes, about 8 fatalities could occur in the nationwide general population from transportation activities of the mostly legal-weight truck scenario and about 5 fatalities from the mostly rail scenario during the 24-year transportation period (impacts of a maximum reasonably foreseeable accident are not included).

Impact analyses for the transport of spent nuclear fuel and high-level radioactive waste in Nevada using a branch rail line are based on the assumption that the branch rail line would be dedicated to activities related to the Proposed Action. There are other possible uses for such a branch rail line in Nevada including support of ranching, industrial, and commercial endeavors; support of Federal, state, tribal and local government activities; and transport of people, materials, and products into, out of, and across the state. However, DOE has not addressed any of these possibilities because there are no concrete proposals at this time for alternative uses, and insufficient information exists to evaluate such uses. Potential uses of a branch rail line are identified in Chapter 8, but the need or level of use and growth of use has not been defined or evaluated. If the Yucca Mountain Site was designated, DOE would consider any uses that were reasonably foreseeable at that time other than transporting radioactive materials to the site in selecting an alignment within any rail corridor selected.

Impacts of Loading Operations

All spent nuclear fuel and high-level radioactive waste would be loaded onto trucks or railcars at the 77 sites for transport to the Yucca Mountain site. Some health and safety impacts would be associated with these loading operations. There would be small (0.04 latent cancer fatality) impacts to members of the public from loading operations. Over the 24 years of the Proposed Action, an estimated 6 and 2 latent cancer fatalities could occur in involved worker populations from radiation exposure for the mostly legal-weight truck and mostly rail scenarios, respectively. The probability of a latent cancer fatality to the maximally exposed involved worker would be about 0.005 for both scenarios. No worker fatalities from industrial accidents would be expected. No or very small impacts to workers or members of the public would be expected from postulated loading accidents. About 0.4 traffic fatality could occur in the worker population from commuting under the mostly legal-weight truck scenario, while about 0.2 traffic fatality could occur under the mostly rail scenario. Loading operations and potential impacts are discussed further in Section 6.2.2.

Impacts of Incident-Free Transportation

Incident-free transportation is the expected norm for transportation of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site. Impacts of incident-free transportation would include those from external radiation emitted from transportation casks and vehicle exhaust emissions along the transportation routes.

Over the 24 years of the Proposed Action, an estimated 3 (2.5) latent cancer fatalities could occur in the general population along transportation routes from radiation exposure under the mostly legal-weight truck scenario and an estimated 1 latent cancer fatality could occur under the mostly rail scenario. Under the mostly legal-weight truck and mostly rail scenarios, the probability of a latent cancer fatality to the maximally exposed member of the public would be no more than 0.0012 and 0.0001, respectively. Under these same scenarios, about 1 (0.95 for the mostly legal-weight truck scenario and 0.77 for the mostly rail scenario) fatality from vehicle emissions could occur in the general population along transportation routes.

IMPLEMENTING ALTERNATIVES AND SCENARIOS

Implementing alternatives and scenarios are used to describe the range of reasonably foreseeable transportation actions with environmental impacts that could result from the Proposed Action.

Implementing alternatives represent feasible selections that DOE could make based in part on this EIS (for example, selecting a branch rail line corridor or an intermodal transfer station location and an associated route for heavy-haul trucks). Analytical scenarios, on the other hand, are feasible combinations of actions that DOE would have limited ability to direct (for example selecting the use of rail or truck casks for shipments from a specific nuclear powerplant). The scenarios are selected such that the analysis results bound the range of impacts that could result from the Proposed Action.

The transportation modes that make up the analytical scenarios and implementing alternatives include the following:

Legal-weight truck transportation: Legal-weight trucks have gross vehicle weights, including cargo, that do not exceed 80,000 pounds, which is the loaded weight limit for commercial vehicles operated on Interstate and U.S. highways without special state-issued permits. In addition, these vehicles have dimensions that are within the constraints of Federal and state regulation limits.

Permitted overweight, overdimension truck transportation: Semi- and tandem tractor-trailer trucks with gross vehicle weights over 80,000 pounds must obtain permits from state highway authorities to use public highways. States often permit vehicles that have gross weights above 80,000 pounds as *overweight, overdimension* vehicles with operating restrictions to protect public safety. Seven-axle tractor-trailer trucks (steering axle and three drive axles on the tractor and three axles on the trailer) with weights greater than 80,000 pounds that meet Federal bridge formulas and dimensional limits can carry payloads of 70,000 pounds.

Rail transportation: Rail transportation includes railroad transportation of spent nuclear fuel and high-level radioactive waste in large rail transportation casks (rail casks). The casks would be placed on railroad cars at commercial and DOE sites or at nearby intermodal transfer facilities for shipment on trains operated by commercial railroad companies over existing tracks. Because of the weight of the casks, only one cask would be transported on a railcar.

Heavy-haul truck transportation: Heavy-haul truck transportation includes the movement of large rail casks—both loaded and empty—on large heavy-haul trucks traveling on existing highways. For the transportation of spent fuel and high-level radioactive waste rail casks, these vehicles would weigh as much as 500,000 pounds; they would be more than 100 feet long and 10 to 12 feet wide, and would stand as high as 15 feet above the road surface. Heavy-haul trucks would require special permits issued by a state transportation agency. The permits would normally restrict the times of operation (typically daylight, non-rush-hour), operating speeds, and highways used.

Barge transportation: Barge transportation would be the transportation of loaded and empty rail casks between a commercial facility and a nearby railhead using navigable waterways. Barge terminals would have intermodal transfer capabilities sufficient to transfer casks from barges to railcars.

An estimated 12 (11.7) latent cancer fatalities could occur in the worker population from radiation exposure for the mostly legal-weight truck scenario, and an estimated 3 (3.5) latent cancer fatalities could occur for the mostly rail scenario. The probability of a latent cancer fatality to the maximally exposed involved worker would be approximately 0.02 for either the mostly legal-weight truck or mostly rail scenario. DOE expects impacts to noninvolved workers to be even lower than those to involved workers. To assess potential radiological impacts at generator facilities, the EIS analysis assumed that noninvolved workers would have no direct involvement in handling spent nuclear fuel and high-level radioactive waste.

The differences in incident-free impacts between the mostly legal-weight truck and mostly rail scenarios are due principally to (1) the difference in the number of shipments for the two scenarios, and (2) differences in analysis assumptions about the numbers of in-transit stops, the number of potentially exposed persons, and their proximity to shipping casks that could result in external radiation exposure.

DOE identified no national environmental justice concerns or air quality impacts for incident-free transportation. Incident-free national transportation and the potential impacts to workers and the public are discussed further in Section 6.2.3.

Impacts of Transportation Accidents

The analysis evaluated impacts to human health and safety, collectively including the health and safety of the public and transportation workers, from transportation accidents. Thus, impacts to populations from transportation accidents would include impacts to affected workers. Because the population of transportation workers would be small compared to the general population, radiological accident risks and consequences for the worker population would be a small fraction of those estimated for the public (that is, the total population).

TRANSPORTATION ACCIDENT RADIOLOGICAL DOSE RISK

The risk to the general public of radiological consequences from transportation accidents is called *dose risk* in this EIS. Dose risk is the sum of the products of the probabilities (dimensionless) and the consequences (in person-rem) of all potential transportation accidents.

The probability of a single accident is usually determined by historical information on accidents of a similar type and severity. The consequences are estimated by analysis of the quantity of radionuclides likely to be released, potential exposure pathways, potentially affected population, weather conditions, and other information.

As an example, the dose risk from a single accident that had a probability of 0.001 (1 chance in 1,000), and would cause a population dose of 22,000 person-rem in a population if it did occur, would be 22 person-rem. If that population was subject to 1,000 similar accident scenarios, the total dose risk would be 22,000 person-rem. Using the conversion factor of 0.0005 latent cancer fatality per person-rem, an analysis would estimate a health and safety risk of 11 latent cancer fatalities from this population dose risk.

Accident impacts include the consequences where shipping casks could be breached with subsequent release of radioactive material to nearby individuals and populations. In addition, there could be impacts to individuals from “normal” traffic accidents, in which there would be no release of radioactive material from shipping casks and only those directly involved in the accident would be affected. The analysis examined radiological consequences under the maximum reasonably foreseeable accident scenario, and also estimated overall accident risk. The maximum reasonably foreseeable accident scenario is the one with the greatest potential consequences that are reasonably foreseeable. The scenario must also have an occurrence likelihood of 1 in 10 million per year or greater to be considered “reasonably foreseeable.” Accident risk considers the potential consequences of all foreseeable accident scenarios and their occurrence likelihood, ranging from accident scenarios that are likely to occur but would have no release of radioactive material to those accident scenarios that are extremely unlikely to occur but could have large consequences (for example, the maximum reasonably foreseeable accident scenario).

The overall radiological accident risk, as described in Appendix J, Section J.1.4.2.1, from all accident scenarios over the 24 years of transportation activities during the Proposed Action would be about 0.0002 latent cancer fatality for the mostly legal-weight truck scenario and about 0.0005 latent cancer fatality for the mostly rail scenario. These estimated latent cancer fatalities would occur in the hypothetically exposed population residing within 80 kilometers (50 miles) of the accident site.

The maximum reasonably foreseeable accident scenario for the mostly legal-weight truck scenario would result in about 1 latent cancer fatality in the exposed population. It is postulated to involve a release of radioactive material from a truck cask in an urbanized area under stable weather conditions. The probability of this accident scenario would be about 0.00000023 per year (a rate of about 2.3 in 10 million years). The maximum reasonably foreseeable accident scenario for the mostly rail scenario would result in about 5 latent cancer fatalities in the exposed population. It is postulated to involve a release of radioactive material from a rail cask in an urbanized area under stable weather conditions. The probability of this accident scenario would be about 0.00000028 per year (a rate of about 2.8 in 10 million years). The probability of a latent cancer fatality occurring in the hypothetical maximally exposed individual would be about 0.0015 for the mostly legal-weight truck scenario and about 0.015 for the mostly rail scenario.

DOE evaluated accidents involving the crash of a jet airliner into a legal-weight truck cask or rail cask (DIRS 157210-BSC 2001, all). Such an accident could result in up to 0.65 latent cancer fatality.

Nationwide, during the 24 years of the Proposed Action transportation activities, about 5 nonradiological fatalities could result from traffic accidents under the mostly legal-weight truck scenario. For the same time period, about 3 nonradiological fatalities could also result from traffic accidents under the mostly rail scenario. These fatalities would all be related to physical injuries associated with traffic accidents, not radiological impacts.

No environmental justice concerns were identified for transportation accident scenarios. Transportation accident scenarios and potential impacts are discussed further in Section 6.2.4.

Table 6-1 summarizes the national impacts of transporting spent nuclear fuel and high-level radioactive waste from 77 generator sites to the proposed Yucca Mountain Repository. The table lists impacts for the two transportation scenarios—mostly legal-weight truck and mostly rail. It includes impacts that would occur in Nevada among the national impacts. For the mostly rail scenario, Table 6-1 lists a range of impacts. Ten unique national impacts comprise the range—one for each of the five rail and five heavy-haul truck implementing alternatives in Nevada.

As listed in Table 6-1, impacts to the general population would be small for both scenarios. For example, impacts to individuals in a population of between 10 million and 17 million who lived within 800 meters (0.5 mile) of routes and to individuals who used the routes could range from about 0.12 millirem to as much as 0.5 millirem over the 24-year shipping campaign. These small doses would increase the risk of cancer for an average individual who lived along a route by 0.5 to 2.5 in 10 million over the individual’s lifetime. This level of health and safety risk would not be discernible. A hypothetical maximally exposed individual who would live or work along transportation routes for 24 years would receive a dose of 2.4 rem (a truck stop worker for the mostly legal-weight truck scenario) or 0.29 rem (a person who lived near a rail stop for the mostly rail scenario). The estimated dose to the hypothetical truck stop worker would increase the risk of a latent cancer fatality by about 1 in 1,000 over the person’s lifetime. For the maximally exposed individual who lived near a rail stop, the risk of a latent cancer fatality would increase by about 1 in 10,000 over the person’s lifetime. The health and safety risks for these hypothetical individuals would not be discernible. For perspective, in the United States, about one in four deaths is caused by cancer from all causes.

Table 6-1. National transportation impacts for the transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail and mostly legal-weight truck scenarios.[a,b]

Group	Impact	Mostly legal-weight truck scenario	Mostly rail scenario
Worker	*Incident-free health impacts, radiological*		
	Maximally exposed individual (rem)	48[c]	48[c]
	Individual latent cancer fatality probability	0.02	0.02
	Collective dose (person-rem)	29,000	7,900 - 8,800
	Latent cancer fatality incidence	11.7	3.2 - 3.5[d]
	Industrial safety (fatalities)	0.9	0.29
Public	*Incident-free health impacts, radiological*		
	Average exposed individual (rem)	0.0005	0.0001
	Maximally exposed individual (rem)	2.4[e]	0.29
	Individual latent cancer fatality probability	0.0012	0.00014
	Collective dose (person-rem)	5,000	1,200 - 1,600
	Latent cancer fatality incidence	2.5	0.61 - 0.81
	Incident-free vehicle emissions impacts (fatalities)	0.95	0.55 - 0.77
	Radiological impacts from maximum reasonably foreseeable accident scenario		
	Frequency (per year)	2.3 in 10,000,000	2.8 in 10,000,000
	Maximally exposed individual (rem)	3	29
	Individual latent cancer fatality probability	0.0015	0.015
	Collective dose (person-rem)	1,100	9,900
	Latent cancer fatality incidence	0.55	5
	Accident dose risk (person-rem)	0.46	0.89
	Accident risk (latent cancer fatalities)	0.00023	0.00045
Public and transportation workers	*Fatalities from vehicular accidents*	4.9	2.3 - 3.1

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation, including impacts of loading.
c. Based on 2-rem-per-year dose limit.
d. Range for the 10 rail and heavy-haul truck implementing alternatives in Nevada.
e. Based on 100-millirem-per-year dose limit.

Radiological impacts of transportation accidents, which DOE estimated by summing the products of the probability of releases of radioactive materials from casks and the consequences of the releases if they occurred, would be very small. They would be small because accidents that could cause a release from a cask would be very unlikely and consequences from the small releases that could occur would generally be small. For example, Table 6-1 lists the consequences of maximum reasonably foreseeable accidents for the mostly rail and mostly legal-weight truck scenarios. In these accidents, which would have an annual likelihood of 2.3 in 10 million for the legal-weight truck scenario and 2.8 in 10 million for the mostly rail scenario, the estimated consequences would be 1,100 person-rem for a truck accident and 9,900 person-rem for a rail accident. The health and safety consequences of these doses would be about 0.55 latent cancer fatality for the truck accident and 5 latent cancer fatalities for the rail accident. The risk impacts of these accidents would be 2.3 in 10 million multiplied by 1,100 person-rem for the truck accident—about 0.00025 person-rem—and about 2.8 in 10 million multiplied by 9,900 person-rem for the rail accident—about 0.0028 person-rem. A *dose risk* of 0.0028 person-rem to a population is equivalent to a risk of 1 in 1 million of a single latent cancer fatality in the population. Thus, the radiological risks to health and safety from transportation accidents would be exceedingly small for both scenarios.

The radiological risks of accidents for the general public are not comparable with the risks of fatalities associated with immediate nonradiological consequences of transportation accidents. For the mostly legal-weight truck scenario, the analysis estimated there could be as many as 5 (4.9) fatalities over 24 years from vehicle collisions and other traffic accidents during the 53,000 legal-weight truck and 300 rail shipments. For the mostly rail scenario, which would involve as many as 9,600 rail and 1,100 legal-weight truck shipments, the analysis estimated there could be about 3 (2.5 to 3.3) fatalities over 24 years attributable to train operations; these could include fatalities from grade-crossing accidents and trespassers struck and killed by trains.

The analysis estimated long-term health effects fatalities that could be caused by the exhaust and fugitive dust emissions of the vehicles that would transport spent nuclear fuel and high-level radioactive waste. There would be 1 (0.95) fatality under the mostly legal-weight truck scenario and less than 1 (between 0.55 and 0.77) fatality under the mostly rail scenario as a consequence of 24 years of transportation. These fatalities would be latent, or would occur well after exposure to the vehicle exhaust and dust emissions.

Radiological doses to the workers who would load casks, drive trucks, operate trains, and inspect vehicles in transit would be higher than doses to the general public. Radiological protection programs would manage and limit doses to workers whose jobs would cause them to receive the greatest exposures. Even so, the analysis assumed a maximally exposed individual worker could receive a dose as high as 2 rem per year for each of the 24 years of the Proposed Action, for a total of 48 rem over 24 years. The analysis assumed that this dose, which is the maximum currently allowed under DOE administrative controls, would occur for both the mostly legal-weight truck and mostly rail scenarios. A dose of 48 rem would increase the worker's lifetime risk of a latent fatal cancer from an average of 23 percent from all causes to 25 percent.

The radiological impacts to all workers involved in shipping spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository would be greatest for the mostly legal-weight truck scenario. For this scenario, the analysis estimated the workers would receive a total dose of 29,000 person-rem. Thus, the estimated lifetime impact to the worker population for the mostly legal-weight truck scenario would be 11.7 latent cancer fatalities from shipments over the 24 years of the Proposed Action. For the mostly rail scenario, the estimated lifetime impacts would be between 7,900 and 8,800 person-rem, or about one-third of the impacts for the mostly legal-weight truck scenario.

6.1.2 OVERVIEW OF NEVADA TRANSPORTATION IMPACTS

This section provides an overview of the environmental impacts associated with transportation of spent nuclear fuel and high-level radioactive waste in the State of Nevada. Although this section provides a more detailed, regional subset of some of the information gathered and analyses conducted for national transportation (see Section 6.1.1), it also includes information analyzed specifically for Nevada. This includes impacts from construction and operation of branch rail lines, routes for heavy-haul trucks and intermodal transfer stations, commuter transportation for construction and operations activities, and transportation of other materials in support of Yucca Mountain operations. Detailed discussions of potential impacts in Nevada are in Section 6.3 and Appendix J. The following areas were evaluated for potential impacts in Nevada from Yucca Mountain transportation activities:

- Transporting spent nuclear fuel and high-level radioactive waste by legal-weight truck in Nevada
- Constructing a branch rail line in Nevada and using it to transport spent nuclear fuel and high-level radioactive waste by rail to the repository
- Upgrading highways in Nevada for use by heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the repository
- Constructing and operating an intermodal transfer station in Nevada
- Transporting materials, consumables, supplies, equipment, waste, and people to support construction, operation and monitoring, and closure of the repository

Overviews are presented for the 12 environmental resource areas analyzed in this chapter and for the transportation of other materials and supplies, which is presented in further detail in Appendix J. Section 6.3 contains summaries that provide information for assessing the relative impacts in these resource areas from the mostly legal-weight truck transportation scenario, the five implementing alternatives for rail transportation, and the five implementing alternatives for heavy-haul truck transportation.

6.1.2.1 Land Use

Land-use impacts (land areas that would be disturbed or whose ownership or use would change) would be greatest for the mostly rail scenario. Land-use and ownership impacts based on a 60-meter- (200-foot)-wide rail right-of-way (land withdrawn) would affect from approximately 9.4 square kilometers (2,323 acres) for the Valley Modified route to 33.2 square kilometers (8,204 acres) for the Caliente route. Actual land disturbance in each 400-meter- (0.25-mile)-wide corridor for individual rail routes would range from approximately 5.1 square kilometers (1,260 acres) for the Valley Modified route to approximately 19.2 square kilometers (4,744 acres) for the Carlin route (see Figure 6-3). DOE based these estimated disturbances on anticipated construction activities (borrow areas, construction camps, soil areas) in the 400-meter corridor associated with the construction of a railroad and the projected width of the average construction disturbance for each rail bed. The average disturbance widths, for example, range from approximately 28 meters (91 feet) for the Caliente-Chalk Mountain Corridor to approximately 37 meters (120 feet) for the Jean Corridor. Land disturbance calculations do not include access roads. Existing roads would be used where possible. Due to possible variations along the rail corridors, land-use, ownership, and disturbances could vary from those discussed above (see Appendix J, Section J.3.1.2). Section 6.3.2.2 reports ranges due to these variations, as well as information on the representative corridor routes. No prime farmland would be affected by any of the transportation routes. The Carlin Corridor would affect the most private land [14 square kilometers (3,459 acres)]. Table 6-2 summarizes the land-use conflicts along the corridors. Selecting variations of a corridor, as described in Appendix J, Section J.3.1.2, could reduce some conflicts and increase or change conflicts in others. Overall impacts are generally proportional to the length of the corridor.

Disturbed land area for all of the heavy-haul truck implementing alternatives would range from 0.83 to 3.6 square kilometers (205 to 890 acres). No more than 0.2 square kilometer (50 acres) of private land would be affected for any route. There would be no land-use impacts from legal-weight trucks using existing highways. Land-use impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively. None of the transportation implementing alternatives currently being considered would be affected by the flexible design evaluated for the proposed repository. Chapter 2, Table 2-7, summarizes the impacts to the various resource areas as the result of the repository operating modes. Section 6.3 contains summary information about the impacts in Nevada from the mostly legal-weight truck scenario and the rail and heavy-haul alternatives of the mostly rail scenario.

There are potential land-use conflicts for the Nevada implementing alternatives. The Carlin, Caliente, and Valley Modified Corridors encroach on the western and southern boundaries of the Nellis Air Force Range (also known as the Nevada Test and Training Range), and the Caliente-Chalk Mountain rail corridor and Caliente/Chalk Mountain heavy-haul truck route travel through the Range from north to south, essentially bisecting it. The U.S. Air Force has stated to DOE that the construction and use of routes through the Nellis Air Force Range would seriously affect sensitive and classified programs, would severely reduce Air Force training capabilities, and would impair the ability to comply with international testing and training obligations on the Range. In response to these concerns, DOE has identified the Caliente-Chalk Mountain Corridor and Caliente/Chalk Mountain heavy-haul route as nonpreferred alternatives. In addition, the Air Force noted the potential for safety risks of using other routes that could cross lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. Although DOE is unaware of specific safety risks, the Caliente, Carlin, and Valley Modified rail corridors

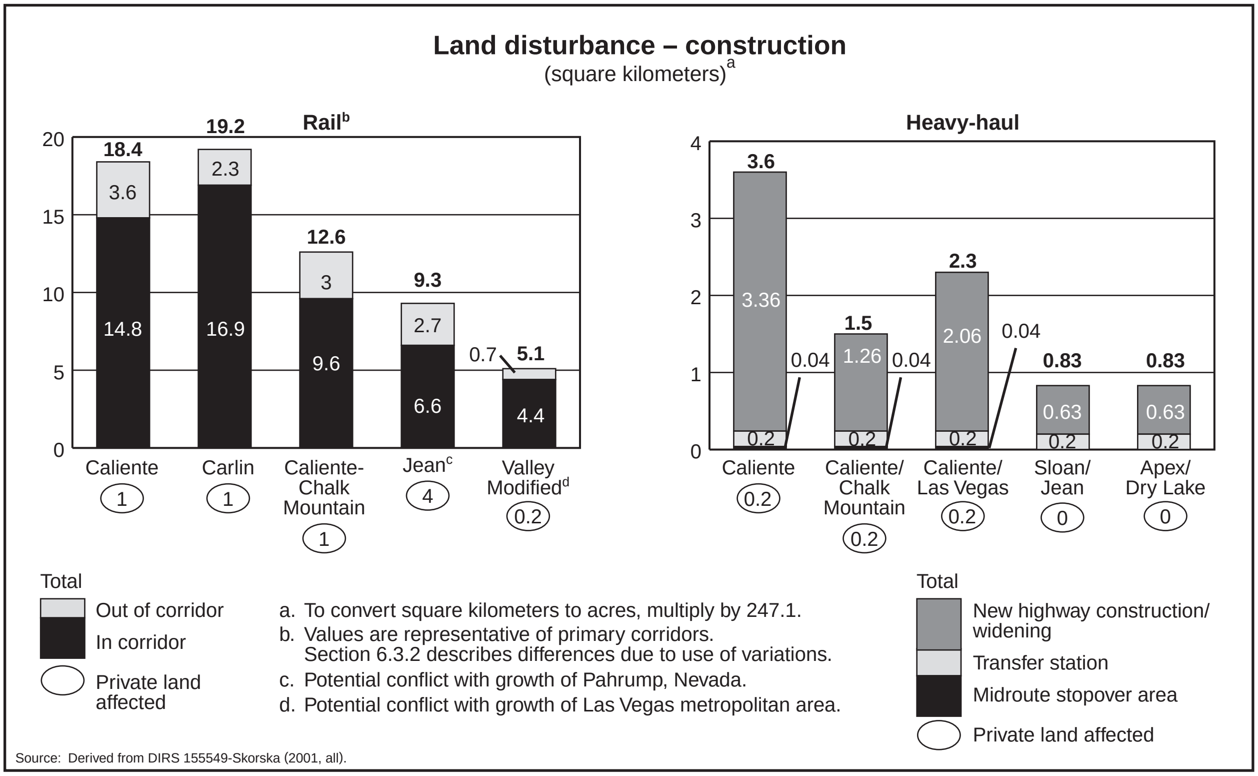

Figure 6-3. Land disturbed for construction of branch rail lines and upgrades to Nevada highways for heavy-haul use.

include sections that would encroach on the Range for short distances. For the Caliente Corridor, Carlin Corridor, and one section of the Valley Modified Corridor, DOE has identified variations that would avoid entering the Range. A short segment of the Valley Modified Corridor for which there is no currently identified variation would cross the southern Range boundary. If DOE selected this corridor, it would consult with the Air Force to determine avoidance or mitigation measures.

The Steiner Creek Alternate of the Carlin Corridor passes just west of the Simpson Park Wilderness Study Area and might encroach slightly into the Wilderness Study Area. The Caliente Corridor passes close to the Weepah Springs and Kawich Wilderness Study Areas, and passes inside and along the western boundary of the South Reveille Wilderness Study Area. The Wilson Pass Option of the Jean Corridor passes through Bureau of Land Management Visual Resource Management Class II lands in the vicinity of Wilson Pass in the Spring Mountains. The Jean and Valley Modified Corridors could have conflicts with the future community growth of Pahrump and Las Vegas, respectively. The Valley Modified Corridor passes near the Las Vegas Paiute Indian Reservation. The Valley Modified Corridor and its Sheep Mountain Alternate cross Nellis Wilderness Study Areas A, B, and C; the Quail Mountain Wilderness Study Area; and penetrates the Desert National Wildlife Refuge. The routes for heavy-haul trucks pass through the Las Vegas Paiute Indian Reservation along U.S. Highway 95 northwest of Las Vegas and approximately 4.8 kilometers (3 miles) west of the Moapa Indian Reservation. The rail origination location for the Stateline Pass Option is on lands to be used for the construction of the Ivanpah Valley Airport (Ivanpah Valley Airport Public Lands Transfer Act, Public Law 106-362, 114 Stat. 1404). The Bonnie Claire Alternate of the Carlin and Caliente Corridors passes through the newly established Timbisha Shoshone trust lands near Beatty.

Table 6-2. Land-use conflicts of rail corridor variations.[a,b]

Corridor[c]	Forest Service land	Fish and Wildlife Service land/ range	Desert Land Entry Program/ withdrawal area	Right-of-way/ road	Wilderness Study Area	Private land	Grazing allotments	Nellis Air Force Range	BLM[d]/ Nevada Test Site land	Native American Reservation
Caliente										
Caliente Corridor with Eccles Option	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Eccles Option	No	No	No	No	No	Yes	Yes	No	Yes	No
Caliente Option	No	No	No	Yes	No	Yes	No	No	Yes	No
Crestline Option	No	No	No	Yes	No	Yes	No	No	Yes	No
White River Alternate	No	No	No	No	No	Yes	No	No	Yes	No
Garden Valley Alternate	No	No	No	Yes	No	Yes	No	No	Yes	No
Mud Lake Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Goldfield Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Bonnie Claire Alternate	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Oasis Valley Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Beatty Wash Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Carlin										
Carlin Corridor with Big Smoky Valley Option	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No
Big Smoky Valley Option	No	No	Yes	Yes	No	No	Yes	No	Yes	No
Crescent Valley Alternate	No	No	No	Yes	No	Yes	Yes	No	Yes	No
Wood Spring Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Rye Patch Alternate	No	No	No	Yes	No	No	Yes	No	Yes	No
Steiner Creek Alternate	No	No	No	No	Yes	No	Yes	No	Yes	No
Monitor Valley Option	No	No	Yes	Yes	No	No	Yes	No	Yes	No
Mud Lake Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Gold Field Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Bonnie Claire Alternate	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Oasis Valley Alternate	No	No	No	No	No	Yes	Yes	No	Yes	No
Beatty Wash Alternate	No	No	No	No	No	No	Yes	No	Yes	No
Caliente-Chalk Mountain										
Caliente-Chalk Mountain Corridor with Eccles Option	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Eccles Option	No	No	No	No	No	Yes	Yes	No	Yes	No
Caliente Option	No	No	No	Yes	No	Yes	No	No	Yes	No
Crestline Option	No	No	No	Yes	No	Yes	No	No	Yes	No
White River Alternate	No	No	No	No	No	Yes	No	No	Yes	No
Garden Valley Alternate	No	No	No	Yes	No	Yes	No	No	Yes	No
Orange Blossom Road Option	No	No	No	Yes	No	No	No	No	Yes	No
Mercury Highway Option	No	No	No	No	No	No	No	No	Yes	No
Topopah Option	No	No	No	No	No	No	No	No	Yes	No
Mine Mountain Alternate	No	No	No	No	No	No	No	No	Yes	No
Area 4 Alternate	No	No	No	Yes	No	No	No	No	Yes	No
Jean										
Jean Corridor with Wilson Pass Option	No	No	No	Yes	No	Yes	Yes	No	Yes	No
Wilson Pass Option	No	No	No	Yes	No	Yes	Yes	No	Yes	No
North Pahrump Alternate	No[e]	No	No	Yes	No	Yes	No	No	Yes	No
Stateline Pass Option	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No
Valley Modified										
Valley Modified Corridor	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Indian Hills Alternate	No	Yes	Yes	Yes	No	No	No	No	Yes	No
Sheep Mountain Alternate	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No
Valley Connection	No	No	No	No	No	Yes	No	No	Yes	No

a. Sources: Derived from DIRS 101504-BLM (1979, all), DIRS 103077-BLM (1983, all), DIRS 101523-BLM (1994, all), DIRS 103079-BLM (1998, all), DIRS 104993-CRWMS M&O (1999, all), DIRS 155549-Skorska (2001, all).

b. For definition and illustration of Corridor, Option, Variation, and Alternative terms, see Chapter 3, Section 3.2.2. For additional explanation, see Appendix J, Section J.3.1.2.

c. The first line under each corridor indicates land-use conflicts for the entire corridor with the use of that particular variation. Further listings indicate conflicts only along the length of the particular variation.

d. BLM = Bureau of Land Management.

e. Route abuts Toiyabe National Forest.

6.1.2.2 Air Quality

The main air pollutants would be fugitive dust (PM_{10}) and equipment emissions (carbon monoxide, nitrogen dioxide, and sulfur dioxide) from construction or upgrade activities associated with the rail and heavy-haul truck implementing alternatives, and vehicle emissions associated with legal-weight truck, heavy-haul truck, and rail transportation.

Because the Las Vegas air basin is in nonattainment of air quality regulations for PM_{10} and carbon monoxide, more restrictive regulations are applied to these criteria pollutants within the Las Vegas air basin. Construction activities are a major source of PM_{10} emissions (DIRS 155557-Clark County 2001, all). Vehicle emissions are the major source of carbon monoxide emissions (DIRS 156706-Clark County 2000, all). The transportation air quality analyses focused on these pollutants and sources within the Las Vegas air basin. Annual emissions were estimated and compared to the General Conformity threshold levels established in EPA regulations implementing the Clean Air Act.

The PM_{10} emissions during construction activities would result primarily from earthmoving operations, but also from construction vehicle fuel combustion. Dust control measures are required for activities in the Las Vegas air basin (DIRS 155557-Clark County 2001, all). These measures include water application and limiting activity on windy days. Construction activities would occur under the rail and heavy-haul transportation implementing alternatives in Nevada. The General Conformity threshold level for PM_{10} (63,500 kilograms per year) would be exceeded under the mostly rail scenario for total estimated emissions of the Valley Modified Corridor (190 percent of threshold). Construction activities in other corridors would not exceed the PM_{10} threshold. The General Conformity threshold level for PM_{10} would be exceeded under the heavy-haul scenario for the Caliente-Las Vegas route (100 percent of threshold). Construction activities of other heavy-haul routes would not exceed the PM_{10} threshold.

Carbon monoxide emissions would largely be a result of vehicle emissions. The greatest vehicle emissions under all three transportation scenarios would result not from radioactive material transport to Yucca Mountain, but from commuter and materials transportation to the site. Transport of personnel and materials results indicate maximum emissions during the operations and monitoring phase (67 percent of the carbon monoxide threshold). Vehicle emissions from transportation of radioactive materials would be, at most, 14 percent of the threshold level for the Valley Modified Corridor. During the construction phase, current estimates of fuel use for construction vehicles would result in exceedances of the General Conformity threshold levels for construction of the Valley Modified Corridor (110 percent of threshold).

Section 6.1.3 discusses air quality impacts from the transportation of personnel and materials. Section 6.3.1 discusses air quality impacts for Nevada legal-weight truck transportation. Sections 6.3.2 and 6.3.3 discuss rail and heavy-haul truck implementing alternatives, respectively.

DOE has conducted a separate conformity review for the Nevada transportation implementing alternatives that could result in the release of pollutants to the Las Vegas air basin, which is in nonattainment for carbon monoxide and PM_{10} (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54). Sections 6.3.1.1, 6.3.2.1, and 6.3.3.1 summarize the results of conformity reviews for legal-weight truck, rail, and heavy-haul truck transportation, respectively, in Nevada.

6.1.2.3 Hydrology

Surface-water resources are most prevalent among the Caliente and Carlin Corridors and could be affected by construction activities. The potential Caliente intermodal transfer station is about 0.19 kilometer (0.12 mile) from a perennial stream, and the Caliente, Caliente/Chalk Mountain, and Caliente/Las Vegas routes for heavy-haul trucks would pass within 1 kilometer (0.6 mile) of water resources. Surface-water impacts during construction would be avoided by implementing good management practices to prevent and mitigate spills of pollutants and would avoid, minimize, or otherwise mitigate possible changes to stream flows. Therefore, DOE does not anticipate impacts to surface waters from the construction of a rail or heavy-haul truck implementing alternative. In addition, surface-water impacts would be unlikely from legal-weight truck, rail, or heavy-haul truck operations or the operation of an intermodal transfer station.

Potential for groundwater impacts would be limited. There would be the potential for temporary withdrawals of water from groundwater sources during the construction of a branch rail line or upgrades to highways and construction of an intermodal transfer station. Estimated water use would be greater for construction of branch rail lines than for upgrades for routes for heavy-haul trucks (see Figure 6-4). Such withdrawals would require temporary permits from the State of Nevada or possibly leases of temporary water rights from individuals along the route. If groundwater could not be withdrawn for construction, water would be transported from permitted sources to the construction sites by truck.

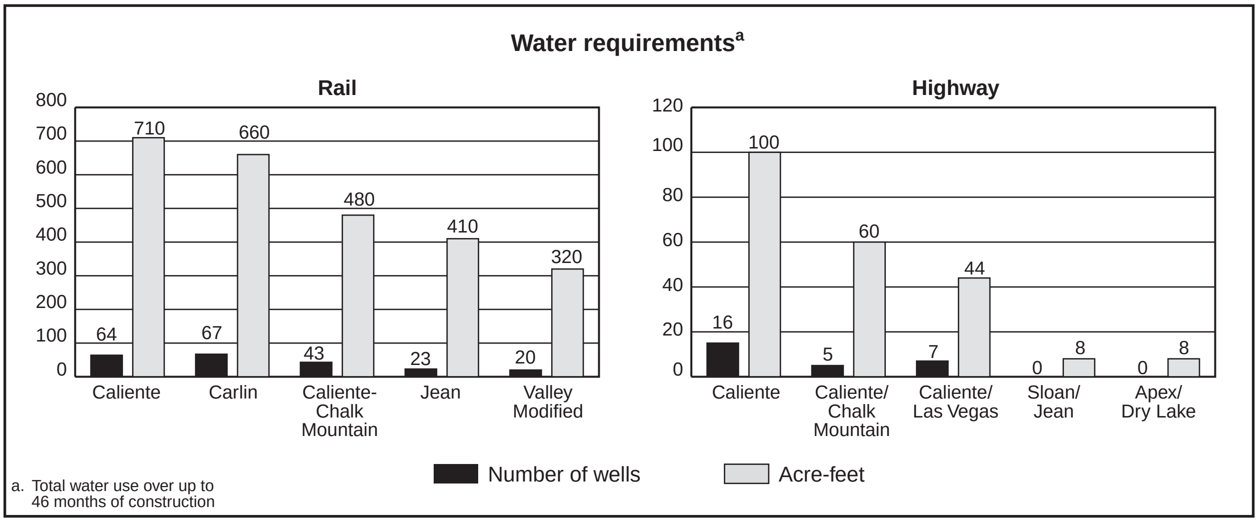

Figure 6-4. Water and number of wells required for construction of branch rail lines and upgrades to Nevada highways for heavy-haul use.

Legal-weight truck shipments, operations of a branch rail line, or operations of heavy-haul trucks, including the operation of an intermodal transfer station, would not affect groundwater resources. Water needs for these operations would be minor, and there would be little potential for contaminant releases to occur, particularly releases of a magnitude that could affect groundwater. Hydrology impacts are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.4 Biological Resources and Soils

Loss of habitat from construction of a branch rail line would be the greatest potential impact to biological resources (vegetation, habitat, threatened and endangered species, small animals, birds, game animals, wild horse and wild burro herds, and soils), potentially affecting the desert tortoise, a threatened species. Loss of desert tortoise habitat would be approximately 2.4 square kilometers (590 acres) for the Caliente/Chalk Mountain route, 3 square kilometers (740 acres) for the Caliente and Carlin routes, 5 square kilometers (1,200 acres) for the Valley Modified route (which is within the range of the desert tortoise along its entire length), and more than 11 square kilometers (2,700 acres) for the Jean route. All of these potential routes have low abundance of desert tortoises with the exception of some limited areas of the Jean route where abundance is higher.

In general, the number of herd management areas crossed by each route is related to the length of the route (as described in Section 3.2.2.1.4). Therefore, the potential for impacts to game animals or horses and burros through disruption of movement patterns or from loss of individual animals would be greater for the longer routes. The Valley Modified route does not cross any herd management areas, but passes through the Desert National Wildlife Range. The Carlin route passes through or near the greatest number of herd management areas or other areas that provide habitat for important biological resources (such as sage grouse strutting grounds). The adverse impact that loss of an individual animal could have on a particular herd would depend on the particular individual that was lost and the size of the herd. Small herds could be affected to a greater degree than large herds. Noise from passing trains could disturb game animals, horses, or burros until those animals became acclimated to the presence of the trains. DOE anticipates that two trains could pass by each day, so this disruption should be minimal.

Other features of the particular routes could affect the potential for impacts to biological resources along each route. Fencing along portions of a route could affect the number of individual animals lost because animals could be blocked from escape routes in fenced areas. Tunnels along the Jean route could be used by wildlife for shelter. Animals seeking shelter in a tunnel might not be able to escape if a train passed through while they were in the tunnel.

The potential for impacts from upgrading Nevada highways for heavy-haul truck use would be small because modifications to roads would occur in previously disturbed rights-of-way. An intermodal transfer station constructed in association with a heavy-haul truck implementing alternative would potentially disturb only about 0.2 square kilometer (50 acres) of potential desert tortoise habitat. The activities associated with constructing a branch rail line, building an intermodal transfer station, or upgrading and maintaining a heavy-haul truck route to Yucca Mountain would be likely to adversely affect a few individual desert tortoises. However, based on review of past experience and available information, DOE believes it could mitigate the impacts of these activities such that they would not negatively affect regional populations of desert tortoises, jeopardize the continued existence of the species, or result in adverse modification of designated critical habitat. Individuals of other special status species could be affected based on the route chosen. Impacts from operations, with the exception of infrequent wildlife kills by vehicles, would be unlikely. Although the proposed routes for heavy-haul trucks pass near or through herd management areas and other areas containing sensitive biological resources, adverse impacts to those resources would be small because the heavy-haul trucks would use existing roads and would represent a very small percentage of the traffic along those roads. [See DIRS 156930-NDOT (2001, all) for traffic counts along Nevada highways.] As with heavy-haul trucks, legal-weight truck shipments that used existing highways would cause only very small impacts to biological resources.

For highway upgrades, DOE or the State of Nevada would reduce concerns about soil contamination or erosion by incorporating appropriate mitigation measures during construction. These measures would include the proper control of hazardous materials and use of dust suppression and other control techniques to reduce erosion. As a result, the implementing alternatives for transportation in Nevada would be unlikely to have impacts on soil. Impacts to biological resources and soils are discussed for Nevada transportation rail implementing alternatives and for Nevada transportation heavy-haul truck implementing alternatives in Sections 6.3.2 and 6.3.3, respectively.

6.1.2.5 Cultural Resources

A comprehensive review of existing literature and many discussions with responsible Federal and State of Nevada agencies and Native American groups has identified many archaeological and cultural sites and features. Pertinent information is presented in Chapter 3, Sections 3.1.6, 3.2.2.1.5, and 3.2.2.2.5. Much of the information has been confirmed and additional information acquired during field observations.

Based on this extensive review of available information and recent field observations, the construction and operation of a branch rail line in any of the candidate corridors could present the potential for direct or indirect impacts (such as crushing or disturbing of sites; soil erosion exposing or covering sites) to archaeological and historic resources, including those related to Native American culture. None of the five rail corridors passes through presently established reservation lands, but the Bonnie Claire Alternate (for either the Carlin or Caliente Corridor) passes directly through the recently established Timbisha Shoshone Trust Lands at Scottys Junction. In some cases, proposed corridors cross historic linear sites (such as the Pony Express Trail) (see Chapter 3, Section 3.2.2.1.5). In these cases potential impacts could be identified during field studies that would evaluate the current condition of the resources at particular locales, the overall character of the impacts, and the effort required to mitigate the impacts. If a rail corridor was selected, DOE would conduct additional archaeological surveys and ethnographic studies as part of additional National Environmental Policy Act reviews to determine potential impacts of alternative alignments within a corridor.

The determination of the potential for impacts to archaeological resources and Native American cultural values from the upgrading and use of existing Nevada highways for heavy-haul truck shipments could require study. Although the widening of roadways and development of turnouts would occur within existing rights-of-way, disturbance of cultural resources near the roadway and, in some cases, within existing rights-of-way could occur. The American Indian Writers Subgroup has commented that ethnographic field studies will be needed to determine specific potential impacts to Native American cultural properties and values for candidate rail corridors (DIRS 102043-AIWS 1998, p. 4-6).

6.1.2.6 Occupational and Public Health and Safety

Impacts to occupational and public health and safety include industrial safety impacts to workers from construction and operations, radiological impacts to workers and the general public from external radiation exposure and exposure to vehicle emissions during normal operations and incident-free transportation, radiological impacts from transportation accident scenarios, radiological impacts from hypothetical severe accident scenarios that would breach shipping casks, and impacts from traffic accidents.

Potential industrial safety impacts to workers from construction and operations are listed in Table 6-3. Estimated impacts from industrial accidents would be higher for rail than for heavy-haul trucks, but in all cases there would be less than 1 industrial safety-related fatality during construction for any of the five branch rail line or five heavy-haul truck implementing alternatives. No industrial safety-related fatalities would be expected to occur during operations.

Table 6-3. Industrial safety impacts to workers from construction and operation of Nevada transportation implementing alternatives.[a]

Impact	Branch rail line				
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Total recordable cases	220	210	180	150	110
Lost workday cases	110	110	95	76	58
Fatalities (industrial accidents)	0.4	0.4	0.4	0.3	0.2
	Heavy-haul truck[b]				
	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake
Total recordable cases	370	320	330	210	210
Lost workday cases	190	170	180	110	110
Fatalities (industrial accidents)	0.9	0.8	0.8	0.5	0.5

a. Impacts are totals for 24 years of operations. There are no impacts for the legal-weight truck scenario.
b. Includes impacts to workers at an intermodal transfer station.

Potential radiological impacts and vehicle emissions-related impacts from normal operations and incident-free transportation in Nevada for each of the rail and heavy-haul truck implementing alternatives and for the mostly legal-weight truck scenario are presented in Table 6-4. Radiological impacts to members of the public from external radiation exposure and risks from exposure to vehicle emissions during incident-free transportation would be lowest for rail, intermediate for heavy-haul trucks, and highest for legal-weight truck transportation, where an estimated 0.3 latent cancer fatalities could occur over 24 years. Impacts from vehicle emissions would be low in all cases (0.001 or fewer fatalities).

Table 6-4. Worker and public health and safety impacts from Nevada transportation implementing alternatives.[a]

Impact	Legal-weight truck[b]	Branch rail line: Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Workers						
Maximally exposed individual probability of LCF[c]	0.02	0.02	0.02	0.02	0.02	0.02
Worker population LCFs	0.75	0.34	0.39	0.3	0.3	0.28
Public						
Maximally exposed individual probability of LCF	0.0016	0.00015	0.00015	0.00015	0.00015	0.00015
General population LCFs	0.17	0.009	0.019	0.009	0.08	0.013
Vehicle emissions-related health effects (fatalities)	0.09	0.25	0.25	0.2	0.23	0.13
Accident risk[d]						
Population LCFs	0.000026	0.000001	0.000001	0.000001	0.000004	0.000001
Maximum reasonably foreseeable accident scenario						
Population LCFs	0.5	5	5	5	5	5
Maximally exposed individual probability of LCF	0.0015	0.02	0.02	0.02	0.02	0.02
Traffic accident fatalities	0.49	1.93	1.85	1.57	1.27	0.94
		Heavy-haul truck[b]: Caliente	**Caliente-Chalk Mountain**	**Caliente/Las Vegas**	**Sloan/Jean**	**Apex/Dry Lake**
Workers						
Maximally exposed individual probability of LCF[c]		0.02	0.02	0.02	0.02	0.02
Worker population LCFs		0.76	0.61	0.66	0.59	0.57
Public						
Maximally exposed individual probability of LCF		0.00016	0.00016	0.00016	0.00016	0.00016
General population LCFs		0.04	0.03	0.11	0.17	0.08
Vehicle emissions-related health effects (fatalities)		0.47	0.32	0.46	0.42	0.29
Accident risk[d]						
Population LCFs		0.000005	0.000001	0.000028	0.00006	0.000028
Maximum reasonably foreseeable accident scenario						
Population LCFs		5	5	5	5	5
Maximally exposed individual probability of LCF		0.02	0.02	0.02	0.02	0.02
Traffic accident fatalities		4.1	2.76	3.47	1.98	1.93

a. Impacts are totals for 24 years of operations.
b. Includes impacts to workers at an intermodal transfer station.
c. LCF = latent cancer fatality.
d. In this table, radiological accident dose risk is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. This sum is converted to latent cancer fatalities using the conversion factor of 0.0005 latent cancer fatality per person-rem.

The overall radiological accident risk from all accidents over the 24 years of transportation activities in Nevada would be no higher than about 0.003 latent cancer fatality in the potentially exposed population within 80 kilometers (50 miles). Accident risk would be highest for the heavy-haul implementing alternatives and lower for the mostly legal-weight truck scenario and rail implementing alternatives. The Jean rail and Sloan/Jean heavy-haul truck implementing alternatives would have higher accident risks than other implementing alternatives. The estimated accident risks are presented in Table 6-4.

The Nuclear Regulatory Commission published a draft Addendum 1 (DIRS 148185-NRC 1999, all) to NUREG-1437, Volume 1, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (DIRS 101899-NRC 1996, all) to provide a technical basis to amend Commission regulations with the objective of improving the efficiency of renewing nuclear plant operating licenses well-understood environmental impacts to avoid repetitive reviews. The addendum addresses two aspects of spent nuclear fuel transportation that the original Commission analysis did not address—the cumulative impacts of transportation of commercial spent nuclear fuel in the vicinity of the proposed repository at Yucca Mountain, and the impacts of transporting higher-burnup fuel. The results of this DOE EIS analysis appear to be consistent with the Nuclear Regulatory Commission conclusion in the addendum, which is that "radiological and accident risks of SNF [spent nuclear fuel] transport in the vicinity of Las Vegas are within regulatory limits and small."

6.1.2.7 Socioeconomics

Socioeconomic impacts of transportation (changes in the level of employment, population, real disposable income, Gross Regional Product, and State of Nevada and local government expenditures) would occur from the construction and operation of a branch rail line, from upgrading a heavy-haul truck route, from transporting large shipping casks using heavy-haul trucks, and from constructing and operating an intermodal transfer station. Figures 6-5 through 6-8 show total regional employment changes in the peak year of construction, and average total employment in the region of influence from operations activities. Because of the large population and employment in the socioeconomic region of influence (principally in Clark County), impacts from construction activities would generally be less than 3 percent of the baseline for each socioeconomic measure in all three counties in the region of influence, for the rail or heavy-haul truck implementing alternatives. Changes in Lincoln County (the two rail corridors and three routes for heavy-haul trucks originating in Caliente) would be more visible, but still generally less than 3 percent of the applicable baseline and would not be greater than historic short-term socioeconomic changes in the county over the past two decades. The operational period for either a branch rail line or a heavy-haul truck route probably would generate relatively constant employment levels. Changes to the baseline regional populations and employment from construction or operation of a rail or heavy-haul truck implementing alternative would be unlikely to have consequences greater than 3 percent of the population baseline. DOE anticipates that the changes in the economic measures of Gross Regional Product, real disposable income, and State of Nevada and local government expenditures would be less than 3 percent of the baselines in each county. Changes in employment and subsequent changes in population would be the principal cause of the changes in these measures. Figures 6-5 through 6-8 show the changes in employment and population expected during construction and operations if DOE implemented one of the five rail or five heavy-haul truck implementing alternatives.

DOE performed detailed analyses for the corridors of the five branch rail line implementing alternatives and the five heavy-haul truck implementing alternatives. The results of these analyses, which are driven by the length of the rail corridors or the cost of construction and upgrades for the proposed routes for heavy-haul trucks, are representative of the variations (options and alternates) of each corridor listed in Appendix J, Section J.3.1.2. The lengths of the variations for each corridor are similar, as listed in Section 6.3.2.2.

In light of public comments received on the Draft EIS concerning perception-based and stigma-related impacts, DOE examined relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently since scoping to allow DOE to quantify the impact of public risk perception on economic development or property values in potentially affected communities. Of particular interest were those scientific and social studies carried out in the past few years that directly relate to either Yucca Mountain or to DOE actions such as the transportation of foreign research reactor spent nuclear fuel. DOE also reevaluated the conclusions of previous literature reviews such as those

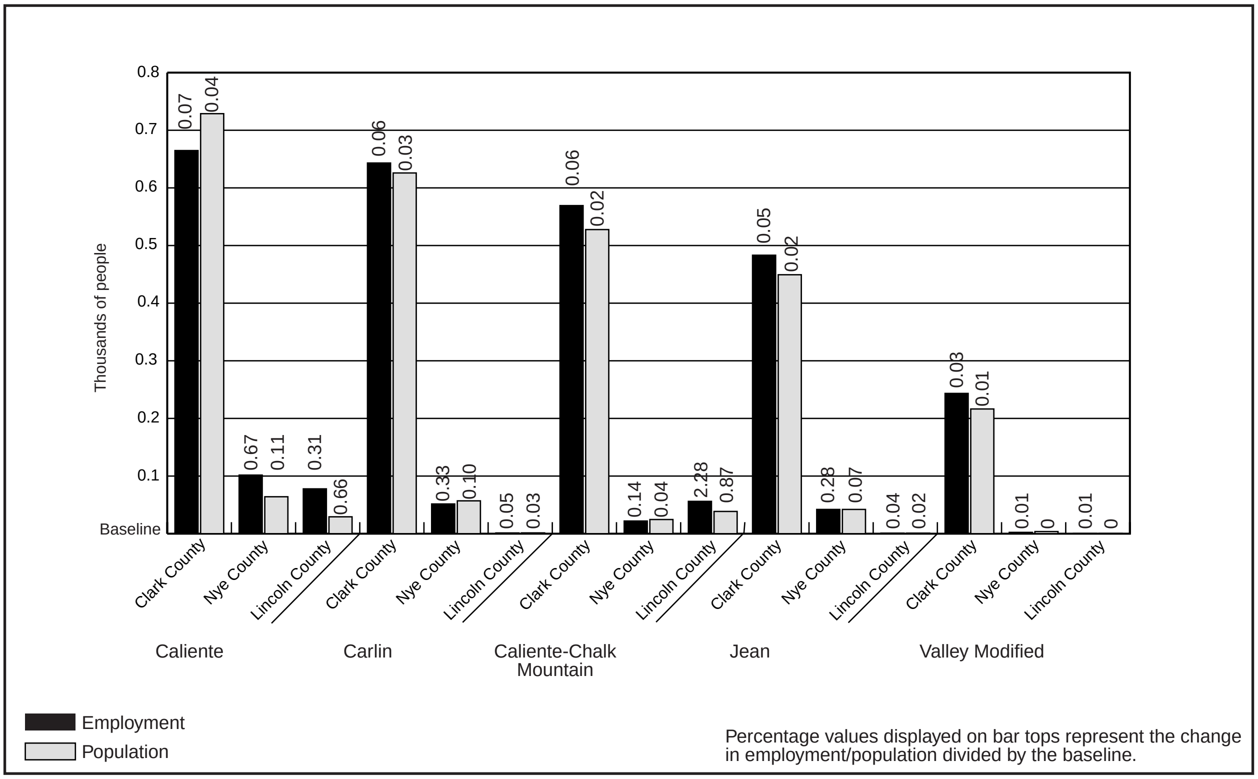

Figure 6-5. Population and employment for branch rail line implementing alternatives, construction (peak years).

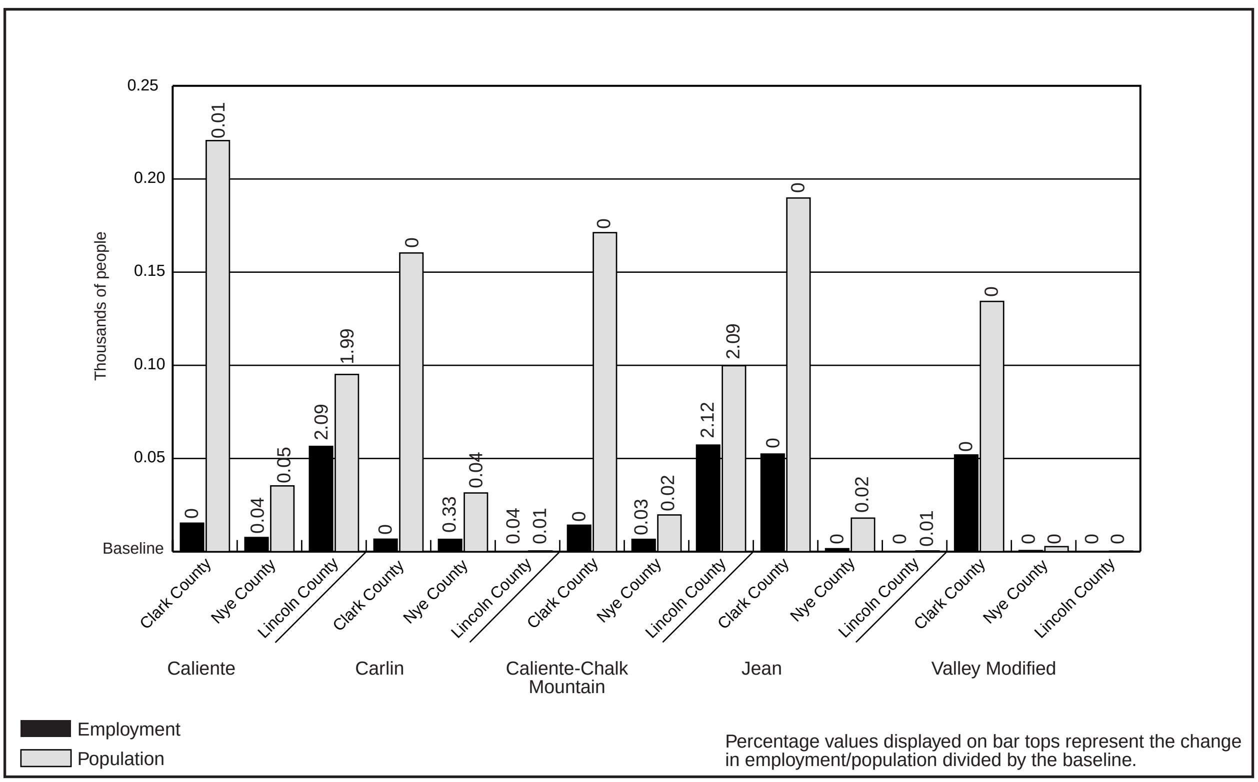

Figure 6-6. Population and employment for branch rail line implementing alternatives, operations (average years).

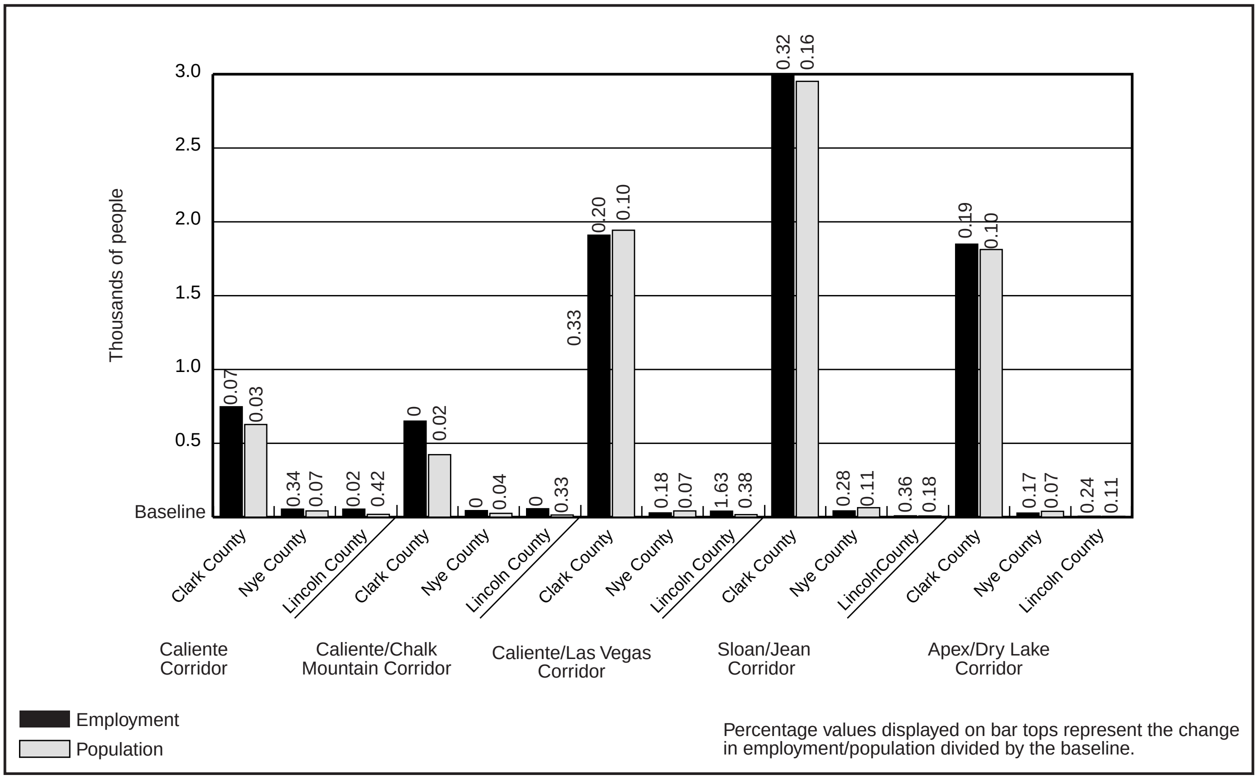

Figure 6-7. Population and employment for heavy-haul implementing alternatives, construction (peak years).

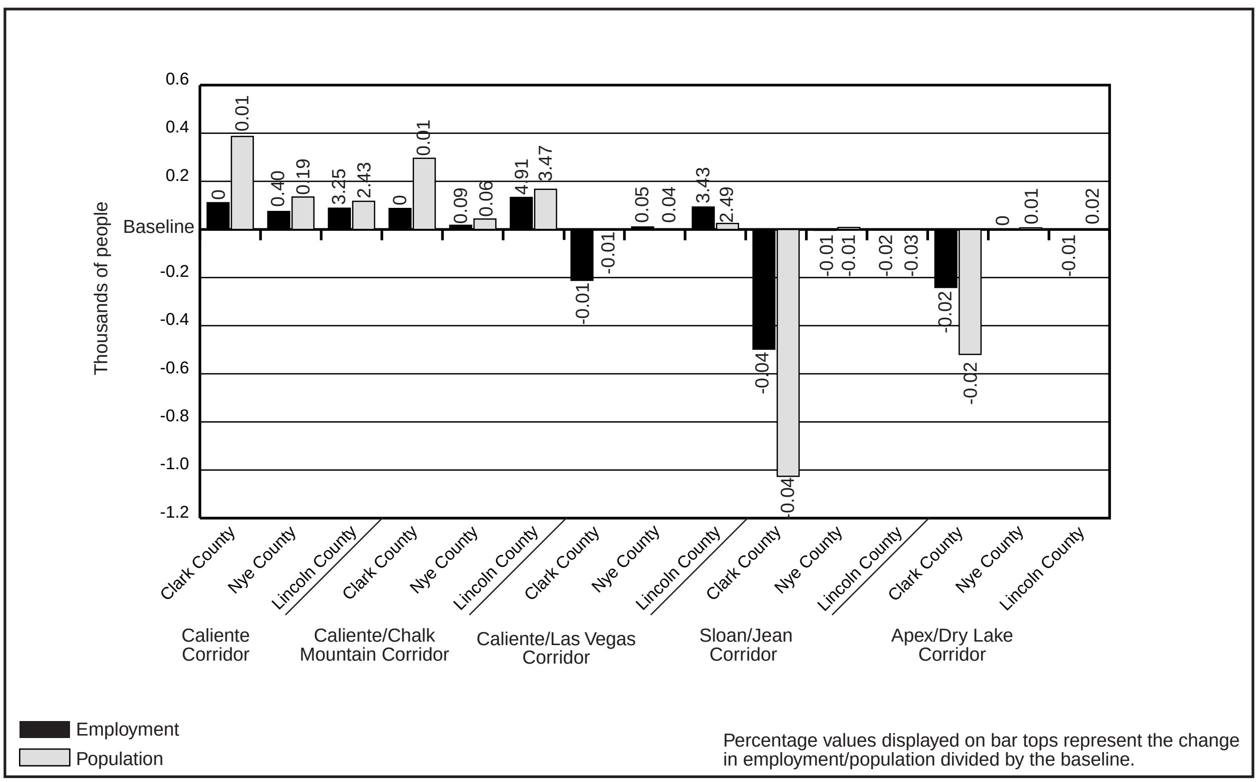

Figure 6-8. Population and employment for heavy-haul implementing alternatives, operations (average years).

conducted by the Nuclear Waste Technical Review Board and the State of Nevada, among others. DOE has concluded that:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be predicted with any degree of certainty
- Much of the uncertainty is irreducible, and
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which may not occur. As a consequence, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this Final EIS. Chapter 2, Section 2.5.4 contains further detail.

6.1.2.8 Noise and Vibration

Noise from the construction of a branch rail line or upgrades to highways for heavy-haul trucks would be transient and not excessive. In addition, noise from trains, which would occur during as many as five weekly round trips, would not be excessively disruptive. Heavy-haul truck operations would use existing highways that already have traffic, including semi-trailer trucks. The American Indian Writers Subgroup identified noise from transportation as a concern because of its effects on ceremonies and the solitude necessary for healing and praying (DIRS 102043-AIWS 1998, all).

Construction upgrades of heavy-haul truck routes and construction of branch rail lines would be unlikely to cause vibration damage to historic buildings because of the distance of potentially sensitive buildings from construction sites. Upgrading of roads where they pass through or near communities would have the most potential for noise or vibration to affect buildings or be a nuisance to residents.

Train Operations. Ground vibration from trains using a branch rail line in Nevada to transport spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be well below levels that would contribute to damage to historic buildings or structures.

Because DOE would place the candidate branch rail lines in areas away from communities, and because development and construction and most operations would occur during daylight hours, the potential for noise or vibration impacts from rail line construction and operation is low.

Heavy-Haul Truck Operation. Because they would use air-filled rubber tires with loads distributed to over 100 wheels and would operate on improved roadways having compacted foundation soils, ground vibration from heavy-haul trucks would be much less than that from trains. In addition, DOE assumes that speeds near communities with sensitive historic structures and buildings would be limited for safety, further ensuring that vibration criteria were not exceeded.

6.1.2.9 Aesthetics

Four of the five candidate rail corridors would not have large or lasting aesthetic impacts. The upgrades of existing highways would present short-term aesthetic impacts during construction but these would be temporary and transient, resulting largely from widening the highways. Routes originating in Caliente could cause impacts on the Class II lands of Kershaw Ryan State Park, the entrance of which is on the east side of the Meadow Valley Wash across from a potential location for an intermodal transfer station. However, the character of this area of the Meadow Valley Wash has been modified by the Union Pacific rail line, the City of Caliente water treatment facility, and agricultural uses of lands in the vicinity. Studies have identified a potential visual resource impact for the northeastern portion of the Jean Corridor that passes through the Spring Mountains. The character of Class II lands (defined in Chapter 3, Section 3.1.10) in that part of the corridor would change, possibly in conflict with visual resource management goals. All routes for heavy-haul trucks and all branch rail lines except Carlin would pass through Class III lands. Aesthetic conditions would not be affected by legal-weight trucks on existing, well-traveled highways.

6.1.2.10 Utilities, Energy, and Materials

Impacts to utility, energy, and material resources from the construction and operation of any of the rail or heavy-haul truck implementing alternatives would be small compared to usage in Nevada. For example, Nevada fossil-fuel consumption during 1996 was about 3.8 billion liters (1 billion gallons) (DIRS 148081-BTS 1999, Table MF-21). By comparison, the largest fossil-fuel use for any of the implementing alternatives would be less than 50 million liters (13 million gallons) over the construction period, or less than 0.5 percent of the Nevada annual use. Similarly, concrete use for the largest implementing alternative would be about 460,000 metric tons (200,000 cubic meters), also less than 2 percent of the Nevada annual use of 7.4 million metric tons (3.2 million cubic meters) (DIRS 104926-Bauhaus 1998, all). Figures 6-9 and 6-10 compare the use of resources for construction of the rail and heavy-haul truck implementing alternatives, respectively.

6.1.2.11 Wastes

Construction and operation of a branch rail line or use of heavy-haul trucks would produce small amounts of construction debris, sanitary solid waste, and sanitary wastewater and possibly a small amount of hazardous waste. Under the heavy-haul truck alternative, a small amount of low-level radioactive waste could be generated at an intermodal transfer station. Nonradioactive wastes would be recovered for recycling, placed in permitted landfills, reused, or in the case of sanitary sewage, treated and disposed of on the site. All waste would be managed in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts to animals, vegetation, air quality, soil, and water resources.

There would be minimal impacts on the capacity of facilities to treat or dispose of wastes from Nevada transportation. For example, branch rail line construction camps with running water would generate about 37 million liters (10 million gallons) of sanitary sewage that could be treated and disposed of in permitted septic systems and about 940 metric tons (1,000 tons) of sanitary solid waste during the peak year of employment. For comparison, the waste volume from Nevada transportation would be small in relation to the volumes disposed of in the State in 2000 [3.5 million metric tons (3.9 million tons) of sanitary solid waste] (DIRS 155565-NDEP 2001, Section 2.1), so the rail construction camps would add about 0.027 percent. The estimated construction debris from an intermodal transfer station would be 23 metric tons (26 tons). Approximately 750,000 metric tons (820,000 tons) of construction debris was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the construction of an intermodal transfer station would add less than approximately 0.01 percent to the total. About 1,400 kilograms (3,000 pounds) of tires and drained oil filters (industrial and special wastes) would be generated during truck maintenance activities at an intermodal transfer station. About 83,000 metric tons (91,000 tons) of this type of waste was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the truck maintenance waste would add less than about 0.01 percent. Hazardous and low-level radioactive waste would have a small impact on the ability of facilities to treat and dispose of the waste. According to the Environmental Protection Agency, treatment and disposal capacity in the western states for hazardous waste would be above the expected demand (by 7 times for incineration and

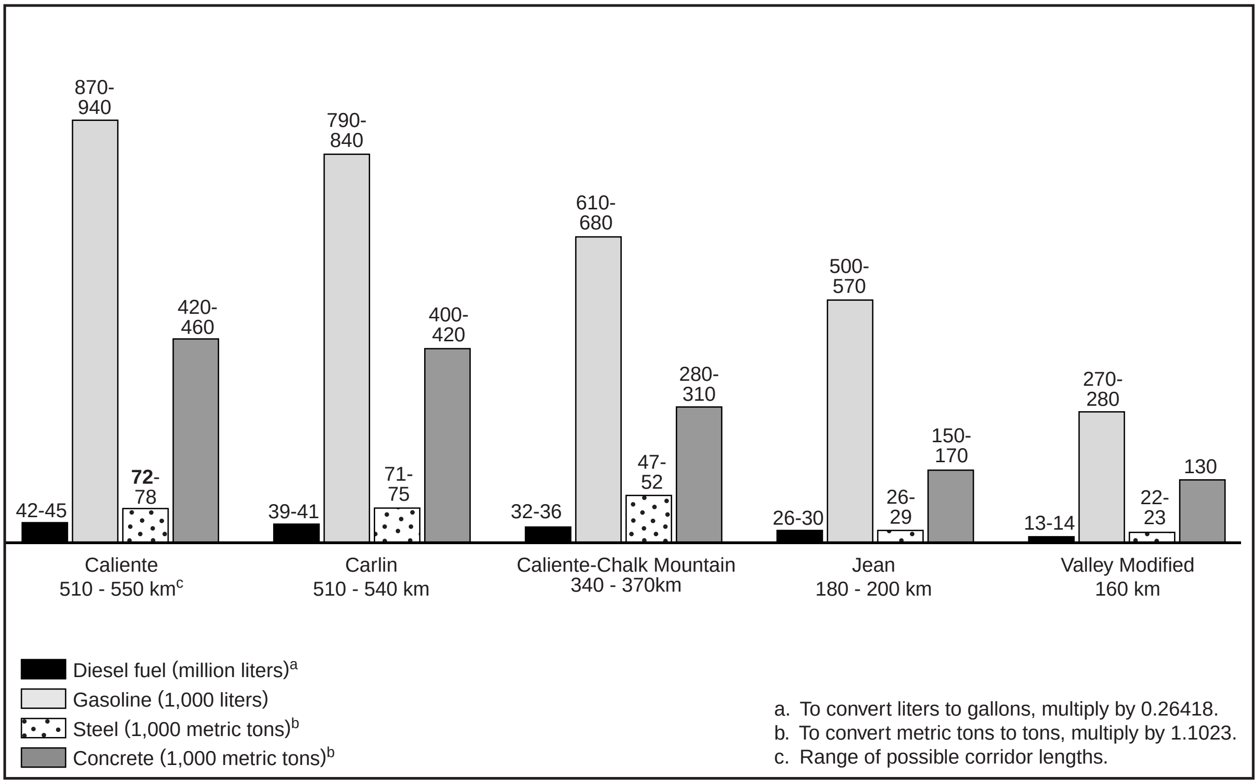

Figure 6-9. Utility, energy, and material use for construction of a branch rail line in Nevada.

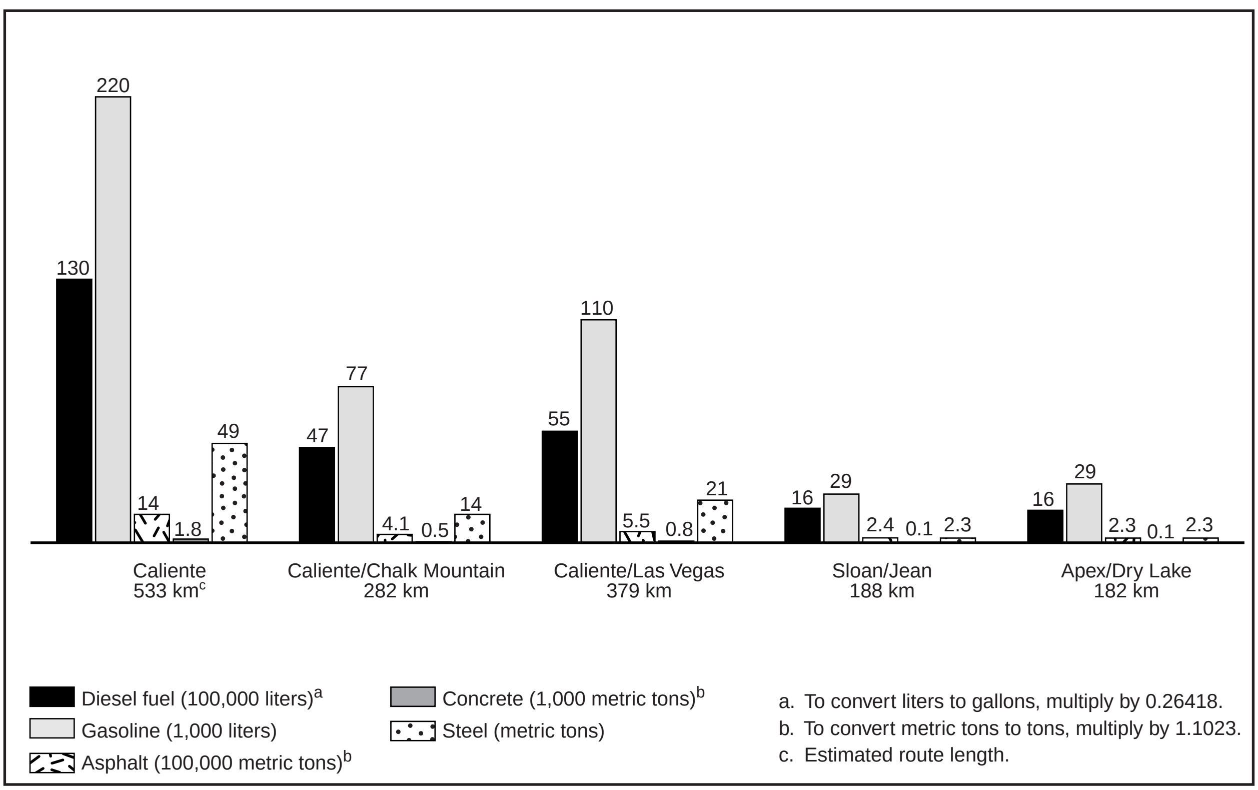

Figure 6-10. Utility, energy, and material use for upgrading of Nevada highways for heavy-haul truck use.

50 times for landfill) until 2013 (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Disposal capacity for a broad range of low-level radioactive wastes would be available at two currently licensed facilities (DIRS 152583-NRC 2000, section on U.S. Low-level Radioactive Waste Disposal).

6.1.2.12 Environmental Justice

Section 6.3 discusses the methods used in the analysis of potential environmental justice concerns. No potentially disproportionately high and adverse impacts to minority or low-income populations were identified in areas of land use; air quality; hydrology; biological resources and soils; socioeconomics; aesthetics; and occupational and public health and safety for construction or operations under the mostly legal-weight truck scenario in Nevada or any of the 10 rail and heavy-haul truck transportation implementing alternatives. Potential visual resource (aesthetic) impacts were identified for the Jean Corridor but these were not determined to be disproportionate. However, no potentially disproportionately high and adverse impacts would occur in these areas for legal-weight truck transportation that would use existing highways. If DOE identified potentially high and adverse impacts for a corridor or route, it would mitigate them (as discussed in Chapter 9).

Because impacts to humans and other impacts that could affect minority or low-income populations or populations of American Indians would not be disproportionately high and adverse, including mitigation as needed, an additional environmental justice analysis is not required. Chapter 4, Section 4.1.13.4, contains an environmental justice discussion of a Native American perspective on the Proposed Action.

6.1.3 TRANSPORTATION OF OTHER MATERIALS AND PERSONNEL

Other types of transportation activities associated with the Proposed Action would involve the transportation of personnel and of materials other than the spent nuclear fuel and high-level radioactive waste discussed above. These other materials include construction materials and consumables for repository construction and operation, including repository components (for example, disposal containers, drip shields, etc.); waste including low-level waste, construction and demolition debris, sanitary and industrial solid waste, and hazardous waste; and office and laboratory supplies, mail, and laboratory samples.

The quantities of construction materials, consumables, site-generated waste, laboratory samples, and supplies, would differ for the range of repository operating modes. The number of commuting employees would also differ. Therefore, the transportation impacts listed in Table 6-5 are ranges, from the least to the greatest impact. Appendix J, Section J.3.6, provides additional detail.

Table 6-5. Impacts related to repository transportation activities.

Factor	Impact
Total kilometers traveled (millions)	610 - 1,100
Total nonradiological latent fatalities[a]	0.9 - 1.6
Total nonradiological traffic fatalities[b]	6.3 - 11.4
Total nonradiological commuting worker traffic fatalities	2.4 - 4.2

a. From commuter and materials transportation.
b. From materials transportation and public fatalities from commuter transportation.

Additional traffic in the Las Vegas air basin would result in emissions of carbon monoxide, most significantly during the repository phases of construction and operation and monitoring. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of vehicle emissions (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). As part of the conformity review DOE conducted using the guidance in DIRS 155566-DOE (2000, all), it was determined that the transportation of personnel, materials, and supplies through the Las Vegas air basin would not exceed the carbon monoxide General Conformity threshold level [91 metric tons (100 tons) per year; 40 CFR 93.153] for serious nonattainment status. The highest total emissions for personnel, materials, and supplies would be 50 tons per year during the construction phase and 67 tons per year during the operations and monitoring phase; emissions would contribute a maximum of an additional 0.07 percent to the estimated 2000 daily carbon-monoxide levels in the nonattainment area (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

Impacts in other environmental resource areas would be unlikely to occur.

6.2 National Transportation

This section describes the estimated national transportation impacts from shipping spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites throughout the United States to the proposed Yucca Mountain Repository. This section includes the following:

- Definition and an overview of the analysis scenarios (Section 6.2.1)
- Impacts to workers and the public from spent nuclear fuel and high-level radioactive waste loading operations at commercial and DOE sites (Section 6.2.2)
- Potential incident-free (routine) radiological impacts and vehicle emission impacts (Section 6.2.3)
- Potential accident scenario impacts (Section 6.2.4).

National transportation of spent nuclear fuel and high-level radioactive waste, which would use existing highways and railroads, would average 7.8 million truck kilometers (4.9 million miles) per year for the mostly truck case and 1.6 million railcar kilometers (1 million miles) per year for the mostly rail case. Barges used to ship rail casks to nearby railheads from commercial sites not served by a railroad could average as much as 6,500 kilometers (4,000 miles) per year. The national yearly average for total highway and railroad traffic is 186 billion truck kilometers (116 billion miles) and 49 billion railcar kilometers (30 billion miles) (DIRS 150989-BTS 1998, pp. 5 and 6)]. Spent nuclear fuel and high-level radioactive waste transportation would represent a very small fraction of the total national highway and railroad traffic (0.004 percent of truck kilometers and 0.003 percent of railcar kilometers). Domestic waterborne trade in 1995 accounted for about 1 billion metric tons (910 million tons) (DIRS 148158-MARAD 1998, all). This represents about 1 million barge shipments per year. Thus, shipments of spent nuclear fuel by barge would only be a very small fraction of the total annual domestic waterborne commerce.

With the exception of occupational and public health and safety impacts, which are evaluated in this section, the environmental impacts of this small fraction of all national transportation would be very small in comparison to the impacts of other nationwide transportation activities. Thus, the national transportation of spent nuclear fuel and high-level radioactive waste would have very small impacts on land use and ownership; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; or waste management.

To determine if pollutants of concern from national transportation vehicles (truck and rail) would degrade air quality in nonattainment areas, DOE reviewed traffic volumes in these areas. This review determined that the numbers of shipments of Yucca Mountain-destined vehicles through these areas would be very small in relation to normal traffic volumes. Therefore, the impact to air quality in these areas, except Nevada (see Section 6.1.3), would be very small.

Radiological impacts of accidents on biological resources would be extremely unlikely. The analysis focused the impacts from accidents on human health and safety. A severe accident scenario, such as the supplies would be 50 tons per year during the construction phase and 67 tons per year during the operations and monitoring phase; emissions would contribute a maximum of an additional 0.07 percent to the estimated 2000 daily carbon-monoxide levels in the nonattainment area (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

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Radiological impacts of accidents on biological resources would be extremely unlikely. The analysis focused the impacts from accidents on human health and safety. A severe accident scenario, such as the maximum reasonably foreseeable accident scenarios discussed in Section 6.2.4.2, that would cause a release of contaminated materials would be very unlikely. The probabilities of the severe accident scenarios discussed in Section 6.2.4.2 are less than 3 in 10 million per year for both the mostly legal-weight truck and mostly rail transportation scenarios. Because of the low probability of occurrence, an accident scenario during the transport of spent nuclear fuel and high-level radioactive waste would be unlikely to cause adverse impacts to any endangered or threatened species, and impacts to other plants and animals would be small. Therefore, the analysis did not evaluate the impacts for these environmental parameters for national transportation activities further.

This chapter does not evaluate the risks of economic loss or resultant environmental consequences from potential transportation accidents that could cause releases of radioactive materials. DOE did not perform these analyses because estimating economic risks and environmental consequences would depend on many factors associated with accidents that cannot be known in advance. Therefore, the information that would be needed for such an analysis is not available. Section J.1.4.2.5 of Appendix J presents a review and analysis of studies by the U.S. Nuclear Regulatory Commission, the National Aeronautics and Space Administration, DOE, and others that discusses cost factors and provides estimates of the range of costs and environmental consequences of cleaning up contamination following hypothetical accidental releases of radioactive materials.

6.2.1 ANALYSIS SCENARIOS AND METHODS

Under the mostly legal-weight truck scenario for national transportation, DOE would transport shipments (with the exception of naval spent nuclear fuel and possibly some DOE high-level radioactive waste) by legal-weight truck to Nevada. Naval spent nuclear fuel would be shipped by rail from the Idaho National Engineering and Environmental Laboratory. Under the mostly-legal weight truck scenario, DOE assumed that some shipments of DOE high-level radioactive waste would use *overweight trucks*. With the exception of permit requirements and operating restrictions, the vehicles for these shipments would be similar to legal-weight truck shipments but might weigh as much as 52,200 kilograms (115,000 pounds). States routinely issue special permits for trucks weighing up to 58,500 kilograms (129,000 pounds).

Figure 6-11 shows the highway routes (mostly Interstate Highways) that the analysis used to estimate transportation-related impacts, along with the locations of the commercial and DOE sites and Yucca Mountain. The routes selected for analysis are representative of routes that DOE could use for truck shipments if the Yucca Mountain site was approved. In addition, the highway routes shown would conform to the routing requirements in 40 CFR 397.101 (see Appendix J, Section J.1.2).

Although DOE cannot be certain of the actual mix of rail and truck shipments that would occur, it expects that the mostly rail scenario best represents the mix of modes it would use. This belief is based on analyses the Department has done to assess generator site capabilities to handle larger (rail) casks, distances to suitable railheads, and historic experience in actual shipments of fuel, waste, or large reactor-related components. In addition, DOE considered relevant information published by knowledgeable sources such as the Nuclear Energy Institute, which provided information on capabilities of generator sites to handle large rail casks (DIRS 155777-McCullum 2000, all). Although DOE believes the mostly rail scenario best represents what would be likely for the transportation of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository, Appendix J, Section J.1.2.1.4 describes an analysis that illustrates how changes in the mix of rail and truck modes would change estimated health and safety impacts for national transportation. The results of the analysis indicated how a mix between the limits represented by the mostly legal-weight truck and mostly rail scenarios would result in health and safety impacts that would be between those estimated for the two scenarios and would not be greater than the impacts from either scenario.

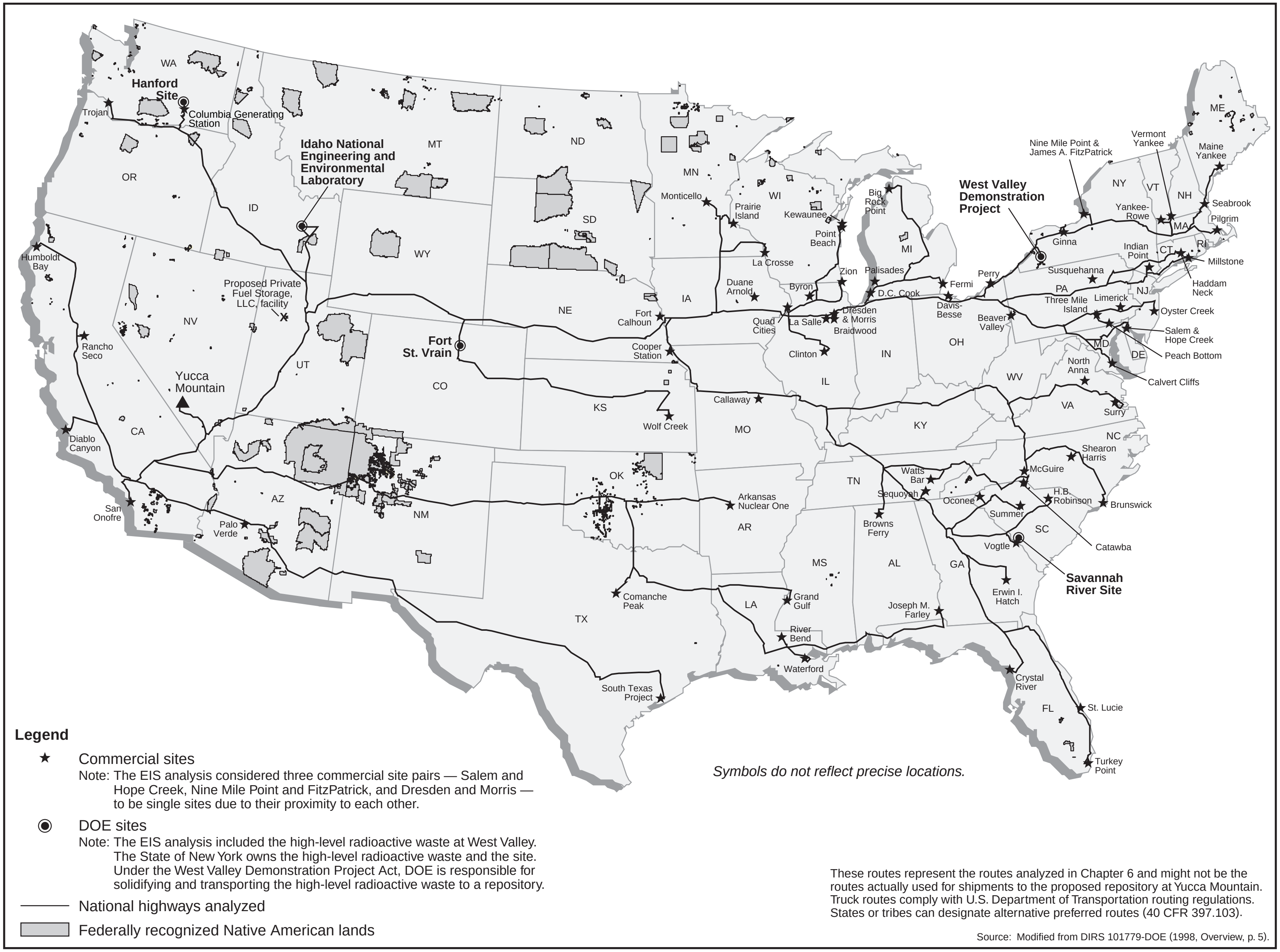

Figure 6-11. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

MOSTLY LEGAL-WEIGHT TRUCK AND MOSTLY RAIL SCENARIOS

The Department would prefer most shipments to a Yucca Mountain repository be made using rail transportation. It also expects that the mostly rail scenario described in this EIS best represents the mix of rail and truck transportation that would be used. However, it cannot be certain of the actual mix of rail and truck transportation that would occur over the 24 years of the Proposed Action. Consequently, DOE used the mostly legal-weight truck and mostly rail scenarios as a basis for the analysis of potential impacts to ensure the analysis addressed the range of possible transportation impacts. The estimated number of shipments for the mostly legal-weight truck and mostly rail scenarios represents the two extremes in the possible mix of transportation modes, thereby covering the range of potential impacts to human health and safety and to the environment for the transportation modes DOE could use for the Proposed Action.

Under the national transportation mostly rail scenario, DOE would transport shipments (with the exception of commercial spent nuclear fuel at six sites that do not have the capability to load a rail cask) by rail to Nevada. In addition, this scenario assumes that 24 commercial sites that have the capability to handle and load rail casks, but that do not have railroad service, would make shipments to nearby railheads by barge or heavy-haul truck. Barge shipments of rail casks containing spent nuclear fuel could be possible from 17 commercial sites that are on or near navigable waterways. Figure 6-12 shows the railroad routes that the analysis used to estimate transportation-related impacts, along with the locations of the commercial and DOE sites and Yucca Mountain. The routes selected for analysis are representative of routes that could be used for rail shipments if the Yucca Mountain site was approved. The analysis estimated that these routes would most closely follow current railroad industry practices and the system-wide capability to ship hazardous materials safely. These routes would reduce time in transit, reduce the number of interchanges between railroads, and use mainline tracks to the maximum practical extent.

The railroad routes shown in Figure 6-12 could also be used by generators to transport spent nuclear fuel to a proposed Private Fuel Storage facility near Skull Valley in northwestern Utah (DIRS 152001-NRC 2000, all). Rail routes from that facility to connections with potential branch rail lines or to an intermodal transfer station in Nevada would be essentially the same as the western sections of rail routes analyzed in this chapter. Thus, impacts presented in this chapter for five candidate routes for heavy-haul trucks and five candidate rail corridors in Nevada would be about the same whether shipments were directly from 72 commercial and 5 DOE generator sites to a Yucca Mountain Repository or from a Private Fuel Storage facility in Skull Valley, Utah. Chapter 8, Section 8.4, discusses potential cumulative impacts of transporting commercial spent nuclear fuel to a Private Fuel Storage facility and then to a Yucca Mountain Repository (see Appendix J, Section J.1.2).

This section evaluates radiological and nonradiological impacts to workers and the public from routine transportation operations and from accidents. DOE used a number of computer models and programs to estimate these impacts; Appendix J describes the analysis assumptions and models.

The CALVIN model (DIRS 155644-CRWMS M&O 1999, pp. 2 to 22) was used to estimate the number of shipments of commercial spent nuclear fuel for both the mostly legal-weight truck and mostly rail scenarios. The CALVIN program used commercial spent nuclear fuel inventories and characteristics from the *Report on the Status of the Final 1995 RW-859 Data Set* (DIRS 104848-CRWMS M&O 1996, all) and the *Calculation Method for the Projection of Future SNF Discharges* (DIRS 156305-CRWMS M&O 2001, all) (see Appendix A) to estimate the number of shipments. For DOE spent nuclear fuel and high-level radioactive waste, the analysis used inventories and characteristics for materials to be shipped under the Proposed Action that were reported by the DOE sites in 1998 (see Appendix A) to estimate the number of shipments. Chapter 2, Section 2.1.3, and Appendix J discuss the number of shipments.

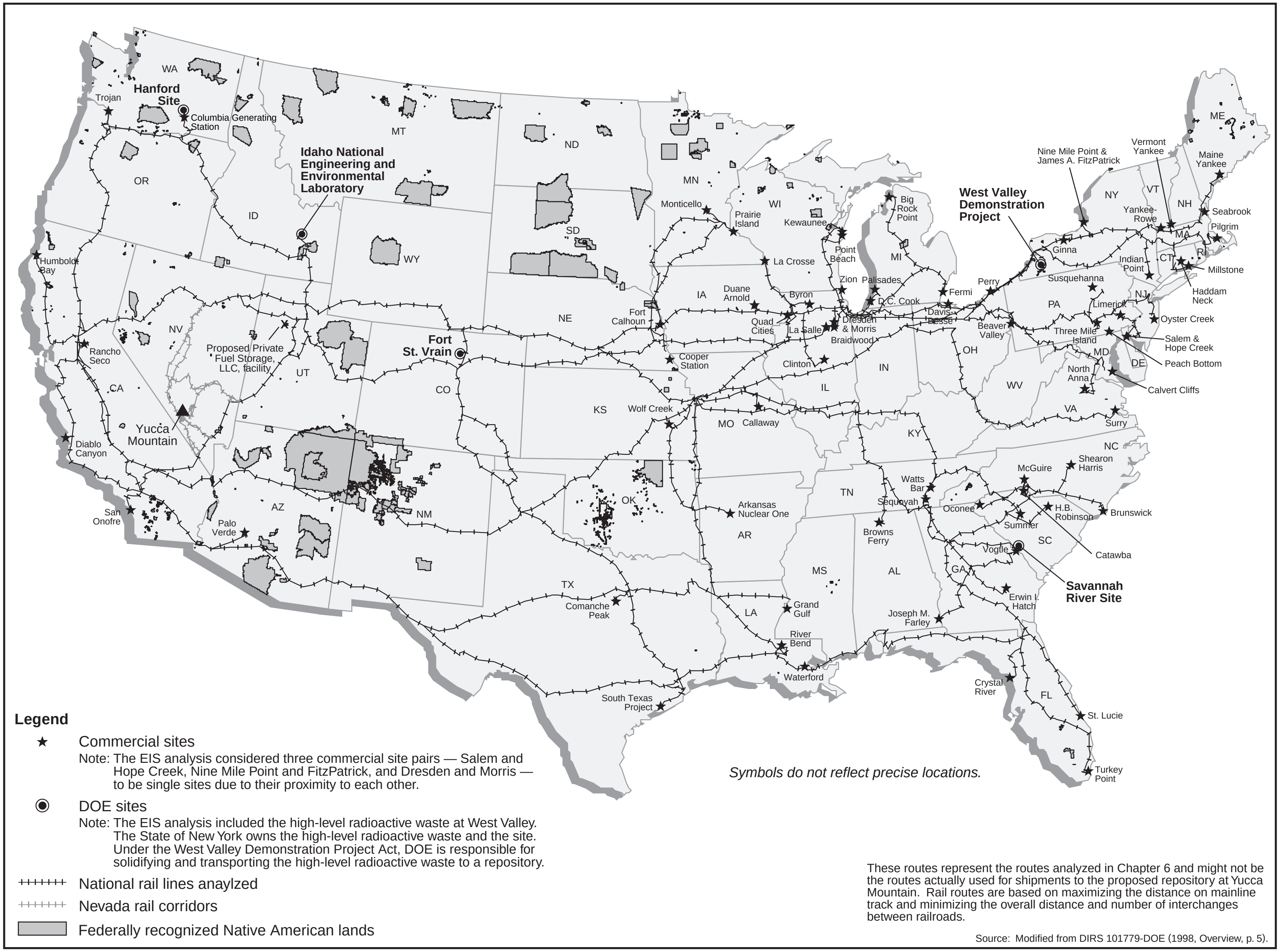

Figure 6-12. Representative rail routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action.

The transportation analyses used the following computer programs:

- HIGHWAY (DIRS 104780-Johnson et al. 1993, all) to identify the highway routes that it could use to transport spent nuclear fuel and high-level radioactive waste. All of the routes would satisfy U.S. Department of Transportation route selection regulations.
- INTERLINE (DIRS 104781-Johnson et al. 1993, all) to identify rail and barge routes for the analysis.
- RADTRAN 5 (DIRS 150898-Neuhauser and Kanipe 2000, all; DIRS 155430 Neuhauser, Kanipe, and Weiner 2000, all) to estimate radiological dose risk to populations and transportation workers during routine operations. The analyses also used this program to estimate radiological dose risks to populations and transportation workers from accidents.
- RISKIND (DIRS 101483-Yuan et al. 1995, all) to estimate radiological doses to the maximally exposed individuals and to the population during routine transportation. This program also estimated radiological doses to the maximally exposed individuals and to the population from transportation accidents.

6.2.2 IMPACTS FROM LOADING OPERATIONS

This section describes potential impacts from loading spent nuclear fuel and high-level radioactive waste in transportation casks and on transportation vehicles at the 72 commercial and 5 DOE sites. It also describes methods for estimating radiological and industrial hazard impacts from routine loading operations and radiological impacts of loading accidents to workers and members of the public. During loading operations, radiological impacts to workers could occur from normal operations and accidents. In addition, workers could experience impacts from industrial hazards. Members of the public could experience radiological impacts if a loading accident occurred but would not experience impacts from industrial hazards, including hazards associated with nonradioactive hazardous materials. Nonradioactive hazardous materials would be used only in small quantities, if at all, in loading operations. Chapter 4 addresses impacts from unloading operations at the repository.

6.2.2.1 Radiological Impacts of Routine Operations

Radiological impacts to members of the public from routine operations would be very small. An earlier DOE analysis estimated that public dose from loading operations (primarily due to atmospheric effluents) would be less than 0.001 person-rem per metric ton of uranium loaded (DIRS 104731-DOE 1986, Volume 2, p. E.6) (see Appendix J for more information). Therefore, to be conservative this analysis estimated the dose to the public from loading operations by multiplying the value of 0.001 person-rem per metric ton of uranium by the 70,000 metric tons (77,000 tons) of spent nuclear fuel and high-level radioactive waste DOE would transport under the Proposed Action. [DIRS 104731-DOE (1986, Volume 2, all) uses the term “metric ton uranium,” which is essentially the same as metric tons of heavy metal for commercial spent nuclear fuel.] The resulting population dose would be 70 person-rem, which, based on conversion factors recommended by the International Commission on Radiological Protection, would result in 0.04 latent cancer fatality. The Commission recommends 0.0004 and 0.0005 latent cancer fatality per person-rem for involved worker populations and the general public, respectively (DIRS 101836-ICRP 1991, p. 22).

Table 6-6 lists estimated involved worker impacts from loading spent nuclear fuel at commercial sites and loading DOE spent nuclear fuel and high-level radioactive waste at DOE facilities for shipment to the Yucca Mountain site under the Proposed Action. The impacts assume worker rotation and other administrative actions at commercial sites would follow guidance similar to that in *DOE Standard - Radiological Control Manual* (DIRS 156764-DOE 1999, Article 211). Although the guidance that the annual dose received by an individual worker could be as high as 2 rem per year, DOE policy is to limit doses to individual workers to no more than 500 millirem per year. The maximum individual dose would be 12 rem over the 24 years of loading operations for individuals who worked the entire duration of repository operations. The estimated probability of a latent cancer fatality for an involved worker from this dose would be about 0.005 (5 chances in 1,000).

Table 6-6. Estimated radiological impacts to involved workers from loading operations.[a]

Impact	Mostly rail	Mostly legal-weight truck
Maximally exposed individual		
Dose (rem)	12[b]	12[b]
Probability of LCF[c]	0.005	0.005
Involved worker population[d]		
Dose (person-rem)	4,200	15,000
Number of LCFs	1.7	6.1

a. Numbers are rounded.
b. Based on 500-millirem-per-year administrative dose limit.
c. LCF = latent cancer fatality.
d. All involved workers at all facilities, preparing about 11,000 shipments under the mostly rail scenario and about 53,000 shipments under the mostly legal-weight truck scenario over 24 years.

As many as 2 latent cancer fatalities from the mostly rail scenario and about 6 latent cancer fatalities from the legal-weight truck scenario could result in the involved worker population over 24 years. The mostly legal-weight truck scenario would result in more potential impacts than the mostly rail scenario because of the increased exposure time needed to load more transportation casks.

To assess potential radiological impacts at generator facilities, the EIS analysis assumed that noninvolved workers would have no direct involvement with handling spent nuclear fuel or high-level radioactive waste. DOE expects radiological impacts to noninvolved workers to be even smaller than those to involved workers.

6.2.2.2 Impacts from Industrial Hazards

Table 6-7 lists estimated impacts to involved workers from industrial hazards over 24 years of loading operations at the 77 sites. Fatalities from industrial hazards would be unlikely from loading activities under either national transportation scenario. The mostly legal-weight truck scenario would have about three times the estimated number of total recordable cases and lost workday cases of the mostly rail scenario because there would be more shipments and more work time (full-time equivalent worker years). Using the assumption that the noninvolved workforce would be 25 percent of the number of involved workers, the analysis determined that impacts to noninvolved workers would be about 25 percent of those listed in Table 6-7.

Table 6-7. Impacts to involved workers[a] from industrial hazards during loading operations.[b]

Impact	Mostly rail	Mostly legal-weight truck
Total recordable cases[c]	130	380
Lost workday cases[d]	67	200
Fatalities[e]	0.29	0.9

a. Includes all involved workers at all facilities during 24 years of repository operations. During the 24 years of shipments to the proposed repository, these workers would put in 1,300 worker years (2,080 hours per worker year) preparing about 11,000 shipments under the mostly rail scenario and 3,700 worker years preparing about 53,000 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments under the mostly legal-weight truck scenario. Industrial safety impacts in the noninvolved workforce would be about 25 percent of those listed.
b. Numbers are rounded to two significant digits.
c. Total recordable cases (injury and illness) based on a 1998 loss incident rate of 0.08.
d. Lost workday cases based on a 1998 loss incident rate of 0.05.
e. Fatalities based on a 1998 loss incident rate of 0.000218.

To assess potential industrial safety impacts at generator facilities, the EIS analysis assumed that noninvolved workers would be persons with office-based administrative duties associated with loading operations. In addition to industrial safety impacts, traffic fatality and vehicle emissions impacts as a result of commuting workers associated with loading operations were estimated. Traffic involving commuting workers could result in 0.4 fatality under the mostly legal-weight truck scenario and 0.2 fatality under the mostly rail scenario. Estimated vehicle emissions impacts from commuting could result in 0.06 latent fatalities for the mostly legal-weight truck scenario and 0.02 for the mostly rail scenario.

6.2.3 NATIONAL TRANSPORTATION IMPACTS

The following sections discuss the impacts of transporting spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository under the mostly legal-weight truck and mostly rail scenarios. The analysis in this section addresses the impacts of incident-free transportation. Section 6.2.4 discusses accidents, and Appendix J contains the details of the analysis and its assumptions.

6.2.3.1 Impacts from Incident-Free Transportation – National Mostly Legal-Weight Truck Transportation Scenario

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals for incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly-legal weight truck scenario.

Incident-Free Radiological Impacts to Populations. Table 6-8 lists the incident-free population dose and latent cancer fatalities to workers and the public for the mostly legal-weight truck scenario. The impacts include those for the shipment of naval spent nuclear fuel by rail to Nevada, intermodal transfer of rail casks to heavy-haul trucks, and subsequent heavy-haul transportation to the proposed repository. Section 6.3.3 and Appendix J contain additional information on worker impacts from intermodal transfer operations. Worker impacts would include radiological exposures of security escorts for legal-weight truck, rail, and heavy-haul truck shipments and from the transfer of naval spent nuclear fuel shipments from rail to heavy-haul truck. The collective dose to the security escorts traveling in separate vehicles would be about 6 person-rem for legal-weight truck shipments. Doses to escorts of rail shipments of naval spent nuclear fuel, who would travel in railcars in sight of but separated from the cask cars, followed by escorted heavy-haul truck shipments in Nevada would be about 0.4 person-rem.

Table 6-8. Population doses and impacts from incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Totals[d]
Involved workers			
Collective dose (person-rem)	14,000	29	14,000
Estimated LCFs[c]	5.6	0.01	5.6
Public			
Collective dose (person-rem)	5,000	20	5,000
Estimated LCFs	2.5	0.01	2.5

a. Impacts are totals for shipments over 24 years.
b. Includes impacts from intermodal transfer operations (see Section 6.3.3.1).
c. LCF = latent cancer fatality.
d. Totals might differ from sums of values due to rounding.

If escorts accompanied legal-weight truck shipments over the full length of their shipment routes, rather than only in highly populated urban areas as required by Federal regulations (10 CFR 73.37), the estimated doses to escorts over 24 years would be 360 person-rem (a 0.14 probability of a latent cancer fatality in the population of escorts).

In addition, as is recommended by the Commercial Vehicle Safety Alliance (DIRS 155863-CVSA 2000, all), the analysis assumed state safety inspections of shipments would occur only in originating and destination states. If inspections were conducted for every shipment in each state through which the shipment would pass, inspectors would receive an additional dose of 7,000 person-rem (about 2.8 latent cancer fatalities) over 24 years.

Appendix J, Section J.1.3.2.2.2 contains additional information about the analysis of impacts to escorts and inspectors.

The estimated radiological impacts would be 6 (5.6) latent cancer fatalities for workers and 3 (2.5) latent cancer fatalities for members of the public for the 24 years of operation. The population within 800 meters (0.5 mile) of routes would be about 10 million based on projections to 2035. About 2.3 million members of this population would be likely to incur fatal cancers from all other causes not associated with the Proposed Action (DIRS 153066-Murphy 2000, p. 5).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-9 lists estimates of doses and radiological impacts for maximally exposed individuals for the legal-weight truck scenario (which considers drivers and security escorts). The risks are calculated for the 24 years of shipment activities. Appendix J discusses analysis methods and assumptions. State inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste and transportation vehicle operating crews would receive the highest annual radiation doses.

Table 6-9. Estimated doses and radiological impacts to maximally exposed individuals for national mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (including driver)	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00005
Public		
Resident along route	0.006	0.000003
Person in traffic jam	0.016[d]	0.000008
Person at service station	2.4[e]	0.0012
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operations.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.
d. Person in a traffic jam is assumed to be exposed one time only.
e. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce impacts to members of the public to below 100 millirem per year.

Impacts to the maximally exposed individuals in the general public would be very low. The highest impacts would be to a service station employee who worked at a station where the analysis assumed all truck shipments would stop under the mostly legal-weight truck scenario (Table 6-9). The analysis estimated that this employee would receive a dose of 2.4 rem over 24 years, which corresponds to the maximum that would be allowed (100 millirem per year) for a member of the general public under regulations in 10 CFR Part 20. The estimate assumes that measures would be taken by DOE to reduce the dose to the employee from 130 millirem per year (3.2 rem over 24 years)—the dose estimated by the analysis if dose reduction measures were not implemented. The estimate of 3.2 rem over 24 years conservatively assumed the person would be exposed to 450 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,200 legal-weight truck shipments per year, about 450 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in 1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 450.

Impacts from Vehicle Emissions. Using data published by DIRS 151198-Biwer and Butler (1999, p. 1165 to 1166), DIRS 155786-EPA (1997, all), and DIRS 155780-EPA (1993, Section 13.2.13) (see Appendix J, Section J.1.3.2.3), DOE estimated the number of fatalities that vehicle emissions from shipments to Yucca Mountain could cause (Table 6-10). These potential impacts would result principally from exposure to increases in levels of pollutants, where the additional pollutants would come from vehicles transporting spent nuclear fuel and high-level radioactive waste and the accompanying escort vehicles. In the context of the number of vehicle kilometers from shipments to the Yucca Mountain site, these emissions would be very small in comparison to the emissions from other vehicles.

Table 6-10. Population health impacts from vehicle emissions during incident-free transportation for national mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel	Total[b]
Estimated vehicle emission-related fatalities	0.93	0.01	0.95

a. Impacts are totals for shipments over 24 years.
b. Total differs from sums of values due to rounding.

This section addresses radiological and nonradiological impacts to populations and maximally exposed individuals from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly rail national transportation scenario. In addition, it identifies impacts of legal-weight truck shipments that would occur under the mostly rail scenario for the six commercial sites that do not have the capability to load rail casks (about 1,079 legal-weight truck shipments over 24 years). Of these six sites, two have direct rail access and four have indirect access. Of the four sites with indirect access, three have barge access. The analysis assumed that the six legal-weight truck sites would upgrade their crane capacities and ship by rail after reactor shutdown.

6.2.3.2 Impacts from Incident-Free Transportation – National Mostly Rail Transportation Scenario

For this analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in Nevada to transport rail casks to and from the repository. Accordingly, the results indicate the range of impacts for the rail and heavy-haul truck implementing alternatives that DOE could use for transportation to the repository after rail shipments arrived in Nevada. Section 6.3 and Appendix J present more information on the analysis of the environmental impacts of the Nevada rail and heavy-haul implementing alternatives. Appendix J, Section J.2, also presents a comparison of the effects of using dedicated trains or general freight services for rail shipments.

The mostly rail scenario assumes that the 24 commercial sites not served by a railroad but with the capability to handle rail casks would use heavy-haul trucks to transport the casks to railheads for transfer to railcars. In addition, 17 of the 24 sites are adjacent to navigable waterways. At some of the 17 sites on navigable waterways, barges could be used for the initial trip segments (see Appendix J, Section J.2.1). The impacts estimated by the analysis include the impacts of heavy-haul truck or barge shipments of rail casks from the 24 sites to nearby railheads.

The analysis assumed that the truck shipments of spent nuclear fuel and high-level radioactive waste would make periodic stops for state inspections, changes of drivers, rest, and fuel. Rail shipments would

VEHICLE EMISSION UNIT RISK FACTORS

DIRS 151198-Biwer and Butler (1999, all) presents unit risk factors for estimating vehicle emissions and the resulting health effects (fatalities) from truck and rail transportation. Changes to information used in the Biwer and Butler analysis resulted in revised factors used in the analyses in this EIS. DOE made four changes:

- *Fugitive dust emission factor*. Biwer and Butler used the paved road fugitive dust emission factor equation from DIRS 155786-EPA (1997, Volume 1, Supplement D, Section 13.2.1) to estimate fugitive dust emission factors for individual vehicle weight classes. The emission factor used in the Final EIS analysis is based on the fleet average weight, as recommended in the reference.

- *Diesel exhaust emission factor*. Biwer and Butler used diesel exhaust emission factors for trucks operating in 1995. The Final EIS analysis used information presented in the *Motor Vehicle-Related Air Toxics Study* (DIRS 155780-EPA 1993, all) to estimate diesel exhaust emission factors projected for the fleet of trucks operating in 2010.

- *Mortality rate used to estimate health effects*. The PM_{10} risk factor used in Biwer and Butler was calculated using a baseline mortality rate of 0.008. This is the crude rate, which is influenced by age differences in population composition. The analysis for the Final EIS used an age-adjusted mortality rate of 0.005.

- *PM_{10} risk factor*. The PM_{10} health risk factor used by Biwer and Butler was based on an upper bound reported by DIRS 152600-Ostro and Chestnut (1998, all), who also presented lower-bound and central estimates. To avoid compounding conservative assumptions, the Final EIS analysis uses the central estimate.

These changes resulted in values for vehicle emission health effect (fatality) unit risk factors that are about a factor of 30 smaller that those estimated by DIRS 151198-Biwer and Butler (1999, all).

also make periodic stops. However, the assumed frequency of the stops and the numbers of people nearby would be different from those for truck shipments and would result in a lower dose.

Incident-Free Radiological Impacts to Populations. Table 6-11 lists incident-free radiological impacts that would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste under the mostly rail national transportation scenario. Because national impacts would result from transportation from the commercial and DOE sites to the repository, they include impacts from a Nevada rail or heavy-haul truck implementing alternative. For the case in which rail shipments would continue in Nevada, total impacts to members of the general public would differ depending on the implementing alternative (see Section 6.3.2 for additional details). The range of values listed in Table 6-11 includes the range of impacts from the Nevada implementing alternatives.

About 1 latent cancer fatality could result from shipments of spent nuclear fuel and high-level radioactive waste under the mostly rail scenario over 24 years. The latent cancer fatality would occur over the lifetime of an individual in the exposed population. The population within 800 meters (0.5 mile) of routes in which this fatality would occur would be approximately 16.4 million. Approximately 3.8 million members of this population would incur fatal cancers from all other causes not associated with the Proposed Action (DIRS 153066-Murphy 2000, p. 5).

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-12 lists the results of risk calculations for maximally exposed individuals for the mostly rail transportation scenario over 24 years. Truck and rail crew members would receive the highest doses. The mostly rail scenario would require transport crews for legal-weight trucks (1,079 total shipments over 24 years) and for rail

Table 6-11. Population doses and radiological impacts from incident-free transportation for national mostly rail scenario.[a]

Category	Legal-weight truck shipments	Rail shipments[b,c]	Totals[d]
Involved workers			
Collective dose (person-rem)	360	3,300 - 4,300	3,700 - 4,600
Estimated LCFs[e]	0.14	1.3 - 1.7	1.5 - 1.9
Public			
Collective dose (person-rem)	130	1,100 - 1,500	1,200 - 1,600
Estimated LCFs	0.07	0.55 - 0.76	0.61 - 0.81

a. Impacts are totals for 24 years.
b. Barge transportation to a railhead on navigable waterways could be used for transportation from 17 commercial sites that do not have rail service but can load a rail cask. See Appendix J.
c. Includes impacts from intermodal transfer station operations.
d. Totals might differ from sums of values due to rounding.
e. LCF = latent cancer fatality.

Table 6-12. Estimated doses and radiological impacts to maximally exposed individuals for national mostly rail scenario.[a,b]

Receptor	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (rail, heavy-haul truck, or legal-weight truck)	48[c]	0.02
Escort	48[c]	0.02
Inspector (rail)	34	0.014
Railyard crew member	4.2	0.0017
Public		
Resident along route (rail)	0.0016	0.0000008
Person in traffic jam (legal-weight truck)	0.016	0.000008
Person at service station (legal-weight truck)	0.075	0.000038
Resident near rail stop	0.29	0.00014

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.

shipments. Individual crew members who operated legal-weight trucks and escorts for rail shipments could be exposed to as much as 48 rem over 24 years of operations (maximum exposure of 2 rem each year). State inspectors who would conduct frequent inspections of rail shipments could receive annual radiation doses as high as 1.4 rem (see Appendix J, Section J.1.3.2.2.2). Escorts traveling with rail shipments could be exposed to up to 48 rem over 24 years of operations (maximum exposure of 2 rem per year; see Appendix J, Section J.1.3.2.2.3).

Impacts from Vehicle Emissions. Less than 1 (a range from 0.55 to 0.77) fatality could result from exposure to vehicle emissions over 24 years under the mostly rail scenario. This potential would arise principally from exposure of people in urban areas to very small increases in levels of pollutants caused by vehicles transporting spent nuclear fuel and high-level radioactive waste.

6.2.4 ACCIDENT SCENARIOS

6.2.4.1 Loading Accident Scenarios

The analysis used existing information from several different sources (DIRS 104794-CRWMS M&O 1994, all; DIRS 103177-CP&L 1989, all; DIRS 103449-PGE 1996, all; DIRS 101816-DOE 1997, all) to estimate potential radiological impacts from accidents involving the loading of spent nuclear fuel or high-level radioactive waste for shipment and handling of shipping casks. As summarized below, the results in these sources indicate that, because no cask would be likely to be breached and thus no radionuclides released, there would be no or very small potential radiological consequences for the public and for workers from accidents in all cases. Appendix J, Section J.1.3.1, presents a description of typical operations for loading spent nuclear fuel in a shipping cask at a commercial facility.

Lift-handling incidents involving spent nuclear fuel in a transfer facility would have an estimated probability of 0.0001 (1 in 10,000) per handling operation (DIRS 104794-CRWMS M&O 1994, pp. 3 to 8). The estimated collective dose to workers from the incidents would be no more than 0.1 person-rem, and it would be much less to the public.

The total number of high-level radioactive waste canisters potentially handled would be approximately the same as the number of spent nuclear fuel canisters, and handling operations would be similar. DOE expects the consequences of handling incidents that involved high-level radioactive waste would be less than those involving spent nuclear fuel (DIRS 103237-CRWMS M&O 1998, p. 3). Thus, impacts from high-level waste handling would be less than the estimated 0.1 person-rem from a spent nuclear fuel handling accident.

Reports on independent spent fuel storage installations and previous DOE analyses provide further evidence of the low probable impacts associated with a loading accident. Safety analysis reports prepared for independent spent fuel storage installations at the Trojan Nuclear Station and the Brunswick Steam Electric Plant concluded that there would be no or low radiological consequences from accidents that could occur at such facilities (DIRS 103449-PGE 1996, Section 8.2; DIRS 103177-CP&L 1989, Section 8.2). This analysis examined the potential magnitude of impacts from spent nuclear fuel storage facility operations. Similarly, previous DOE analyses (DIRS 101816-DOE 1997, all; DIRS 104794-CRWMS M&O 1994, all) indicate that radiological consequences from accidents involving spent nuclear fuel and high-level radioactive waste management activities would be very small (Table 6-12). The low consequences listed in Table 6-13 are consistent with the results from an earlier DOE analysis (DIRS 104731-DOE 1986, Volume 2, p. xvii).

Table 6-13. Radiological consequences of accidents associated with handling and loading operations.

Affected group	Impact (per year)[a]	24-year impact	Source
Involved workers			
Maximally exposed involved worker			
Dose (rem)	0.0005	0.01	--[b]
Probability of LCF[c]	0.0000002	0.000005	--
Worker population			
Collective dose (person-rem)	0.1	2.4	DIRS 104794-CRWMS M&O (1994, p. 3-8)
Number of LCFs	0.00004	0.001	--
Noninvolved workers			
Maximally exposed noninvolved worker			
Dose (rem)	0.0002	0.005	--
Probability of LCF	0.00000005	0.000001	--
Public			
Maximally exposed individual			
Dose (rem)	0.0013	0.03	--
Probability of LCF	0.0000007	0.00002	--
Population			
Collective dose (person-rem)	0.000074	0.002	DIRS 104794-CRWMS M&O (1994, p. 3-8)
Number of LCFs	0.00000004	0.000001	--

a. Average annual impact for 24 years.
b. -- = determined by analysis.
c. LCF = latent cancer fatality.

6.2.4.2 Transportation Accident Scenarios

Accidents could occur during the transportation of spent nuclear fuel and high-level radioactive waste. This section describes the risks and impacts to the public and workers for a range of accident scenarios including those that are highly unlikely but that could have high consequences (called *maximum reasonably foreseeable accident scenarios*) and those that are more likely but that would have less severe consequences. The impacts would include those to the population and to hypothetical maximally exposed individuals. The following paragraphs describe the analysis approach. Appendix J, Section J.1.4, contains more details.

The analysis did not address accident impacts to workers apart from impacts to the public. For example, fatalities from train and truck accident scenarios would include fatalities for vehicle operators. The collective radiological risk from accidents to highway vehicle and train crews would be much less than for the public because of the large difference in the numbers of individuals that could be affected. In addition, based on national accident statistics, motor carrier and train operators are much less likely to be fatalities in nonradiological accidents than operators of other vehicles (DIRS 103410-DOT 1998, p. 30).

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS

Maximum reasonably foreseeable impacts from accident scenarios for the transportation of spent nuclear fuel and high-level radioactive waste would be characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest reasonably foreseeable consequences. For postulated accident scenarios such as these, the forces and heat would exceed the regulatory design limits of transportation cask structures and materials. (The performance of transportation casks was demonstrated through a combination of tests and analyses.) In addition, these forces and heat would be applied to the structures and surfaces of a cask in a way that would cause the greatest damage and bring about releases of radioactive materials to the environment. The most severe accident scenarios analyzed in this chapter would release radioactive material. These accident scenarios correspond to those in the highest accident severity category, which represent events that would be very unlikely but, if they occurred, would result in human health effect consequences.

In general, this EIS considers accidents with conditions that have a chance of occurring more often than 1 in 10 million times in a year to be reasonably foreseeable. Accidents and conditions less likely than this are not considered to be reasonably foreseeable.

The specific number, location, and severity of an accident can be predicted only in general terms of the likelihood of occurrence (the probability). Similarly, the weather conditions at the time an accident occurs cannot be precisely predicted. Therefore, the EIS analysis evaluated a variety of accident scenarios and conditions to understand the influence of various conditions on environmental impacts. The analysis of impacts to populations along routes assumed that an accident could occur at any location along a route.

The EIS analysis considered accident scenarios based on the 19 truck and 21 rail accident cases presented by DIRS 152476-Sprung et al. (2000, all). Appendix J, Section J.1.4.2.1, describes those cases and their derivations. In addition, the analysis estimated impacts of postulated releases from accident scenarios in three population zones—urban, suburban, and rural—under a set of meteorological (weather) conditions that represent the national average meteorology. The analysis used state-specific accident data, the lengths of routes in the population zones in states through which the shipments would pass, and the number of shipments that would use the routes to determine accident scenario probabilities.

The EIS analysis used the properties of a representative commercial spent nuclear fuel along with the properties for the 15 categories of DOE spent nuclear fuel and high-level radioactive waste described in Appendix A. Since the publication of the Draft EIS, DOE has reevaluated the properties of commercial spent nuclear fuel that it used in analyses of transportation accidents and determined that the representative spent nuclear fuel described in Appendix A is more appropriate for analysis of such accidents. Representative commercial spent nuclear fuel would be (1) fuel discharged after 14 years from a boiling-water reactor with a burnup of 40,000 megawatt-days per MTHM and (2) fuel discharged from a pressurized-water reactor after 15 years with a burnup of 50,000 megawatt-days per MTHM. Because representative spent nuclear fuel would be younger and have higher burnup than typical spent nuclear fuel, its relative health and safety hazard would be greater. In fact, the hazard is about 2 times greater. As a consequence, estimates of impacts of transportation accidents involving casks containing representative spent nuclear fuel would be about 2 times greater than if the casks contained typical spent nuclear fuel.

TRANSPORTATION EMERGENCIES

Under Section 180(c) of the Nuclear Waste Policy Act, as amended, the Department would provide technical assistance and funding for training of local and American Indian public safety officials of eligible states and tribes in relation to transportation under the Proposed Action. The training would cover safe routine transportation and emergency response procedures. DOE would also require its transportation contractors to comply with *Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents Involving Truckload Quantities of Radioactive Materials* (DIRS 156289-ANSI 1987, Section 5.2). This standard requires the preparation of an emergency response plan and describes appropriate provisions of information and assistance to emergency responders. The standard also requires the carrier to provide appropriate resources for dealing with the consequences of the accident including isolating and cleaning up spills, and to maintain working contact with the responsible governmental authority until the latter has declared the incident to be satisfactorily resolved and closed. DOE would, as requested, assist state, tribal, and local governments in several ways to reduce the consequences of accidents related to the transportation of spent nuclear fuel and high-level radioactive waste. In addition, DOE maintains an emergency response program through eight Regional Coordinating Offices across the United States. These offices are capable of responding to transportation radiological emergencies and are on call 24 hours a day. They respond to requests for radiological assistance from state or tribal authorities. Other DOE, Federal Emergency Management Agency, and U.S. Department of Transportation programs have provided training for transportation emergencies for many areas (for example, Colorado and South Carolina to support preparation for transportation for the Foreign Research Reactor and Waste Isolation Pilot Plant programs). Appendix M contains additional detail.

In addition to the risk due to accidents involving a release of radioactive material, the analysis examined the impacts of loss-of-shielding accidents. The loss-of-shielding scenarios range from an accident with no loss of shielding to a low-probability severe accident involving both a loss of shielding (and any increased direct exposure) and a release of some of the contents of the cask.

The EIS analysis also estimated impacts from an unlikely but severe accident scenario called a *maximum reasonably foreseeable accident* to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accident scenarios, the consequences were estimated for each of the accident scenarios and for both truck and rail casks from the spectrum of accidents presented in DIRS 152476-Sprung et al. (2000, all). For each accident scenario, possible combinations of weather conditions, population zones, and transportation modes were considered. The scenarios were then ranked according to those that would have a likelihood greater than 1 in 10 million per year and would have the greatest consequences (see Appendix J).

REEXAMINATION OF SPENT FUEL SHIPMENT RISK ESTIMATES

Factors other than the environment can cause uncertainties in the prediction of accident impacts. Uncertainty can result from both limited data and the limitations of computer models used to predict accident impacts. The first comprehensive study that developed estimates of the impacts of severe accidents was the *Shipping Container Response to Severe Highway and Railway Accident Conditions* (DIRS 101828-Fischer et al. 1987, all; also called the *Modal Study*) for fractions of shipping cask contents (spent nuclear fuel or high-level radioactive waste) that such accident scenarios could release to the environment. The estimates of severe accident impacts developed in the Modal Study were reexamined by Sandia National Laboratories in *Re-Examination of Spent Fuel Shipment Risk Estimates* (DIRS 152476-Sprung et al. 2000, all) published in April 2000. The Nuclear Regulatory Commission staff, in a memorandum to the Commissioners, concluded "the best estimate spent-fuel shipment risks from the reexamination appear to be less than the 'Modal Study'-based estimates by as much as 2 orders of magnitude" (DIRS 155562-NRC 2000, all). Although the Commission staff offered this positive finding, it also observed that several questions on the Sandia methodology require resolution before the best-estimate results can be completed. Even though it expressed caution regarding its findings, on the basis of the results presented the Commission staff concluded "the transportation risk studies provide a technical basis for determining that current regulations are sufficient to prevent releases of radioactive material during transport" (DIRS 155562-NRC 2000, all).

6.2.4.2.1 *Impacts from Accidents – National Mostly Legal-Weight Truck Scenario*

This section summarizes the potential impacts and risks associated with accidents under the legal-weight truck scenario. The impacts and risks include those associated with the legal-weight truck and rail shipments to Nevada plus the transfer of the spent nuclear fuel and high-level waste to heavy-haul trucks and its transportation in Nevada. The section summarizes radiological impacts for six accident scenario categories, under two types of weather conditions, and in three population densities (urban, suburban, and rural), in terms of a collective dose risk and consequence (latent cancer fatalities). It describes the potential impacts from the maximum reasonably foreseeable accident scenario separately. It also describes nonradiological impacts in terms of accident fatalities.

Radiological Impacts to Populations from Accidents. Based on state-specific accident rates, the total estimated number of traffic accidents under the Proposed Action for the mostly legal-weight truck scenario would be 66, or 2.8 per year. The collective radiological accident dose risk, as described in Appendix J, Section J.1.4.2.1, would be less than 1 (0.5) person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly legal-weight truck scenario. This calculated risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 0.5 person-rem would be likely to cause much less than 1 (0.0002) latent cancer fatality, or approximately 2 chances in 10,000 of 1 latent cancer fatality among the more than 10 million persons within 80 kilometers of the routes that the shipments would use. The 0.5 person-rem risk includes the dose risk associated with loss-of-shielding events. The accident risk for legal-weight truck shipments dominates the total risk, contributing more than 99.9 percent of the population dose and risk in comparison to the risk associated with the 300 proposed shipments of naval spent nuclear fuel.

Consequences of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized and rural population zones for both legal-weight truck and rail shipments under the mostly legal-weight truck scenario. The maximum reasonably foreseeable transportation accident scenario that would have the greatest consequences for the mostly legal-weight truck scenario (a probability of approximately 3 in 10 million per year) would be a long-duration severe fire accident in which the transportation cask was fully engulfed by the fire. This accident is further described by DIRS 152476-Sprung et al. (2000, p. 7-25) as case 18 in accidents evaluated for legal-weight truck casks (see Appendix J, Section J.1.4.2.1). The analysis assumed that the accident would occur under stable (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time) meteorological conditions in an urban area. Severe accidents in other population zones under stable or neutral weather conditions (atmospheric conditions that would not be exceeded 50 percent of the time) would have smaller consequences. The accident scenario assumes a breach of the shipping cask and the release of a portion of its contents to the air. This accident in combination with stable atmospheric conditions would be very unlikely (2.3 in 10 million per year). Table 6-14 summarizes the impacts of the accident scenario. This accident scenario could cause 0.55 latent cancer fatality; in comparison, a population of 5 million within 80 kilometers (50 miles) of the center of a large U.S. metropolitan area such as that assumed in the analysis would be likely to experience more than 1.1 million lifetime cancer fatalities from other causes not related to the Proposed Action (DIRS 153066-Murphy 2000, p. 5). For this accident scenario, the analysis projected that most of the dose to a population would come from inhalation, cloudshine, and groundshine sources. The maximally exposed individual, assumed to be about 150 meters (490 feet) from the accident where particles heated by the accident would fall after cooling, would receive a dose of about 0.8 rem (Table 6-14). A first responder to this accident would receive a small dose (2.6 millirem).

Table 6-14. Estimated radiological impacts of maximum reasonably foreseeable accident scenario for national mostly legal-weight truck scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident scenario probability (annual)	0.00000023 per year (about 2.3 in 10 million)
Impacts to populations	
Population dose (person-rem)	1,100
Latent cancer fatalities	0.55
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	3
Probability of a latent cancer fatality	0.0015
Impacts to first responder	
Maximally exposed responder dose (rem)	0.26
Probability of latent cancer fatality	0.0000013

In addition to a maximum reasonably foreseeable accident, DOE evaluated other severe accidents. Appendix J, Section J.1.4.2.1, describes these accidents and their potential impacts. The accident conditions for one truck accident (Case 11) could be similar to those from a crash of a commercial jet airliner into a legal-weight truck cask (DIRS 157210-BSC 2001, all). The consequences of this accident (1,100 person-rem or 0.55 latent cancer fatality) would be about the same as those for the maximum reasonably foreseeable truck accident described above.

Section J.1.4.2.5 in Appendix J summarizes studies of potential economic and environmental impacts of hypothetical severe transportation accidents that would release radioactive materials from transportation casks.

Impacts from Traffic Accidents. Approximately 5 (4.9) traffic fatalities could occur in the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck national transportation scenario during the 24 years of operations for the Proposed Action. Essentially all of these fatalities would be from truck operations; none would occur from the 300 railcar shipments of naval spent nuclear fuel. The fatalities would be principally from traffic accidents; half would involve trucks transporting loaded casks to the repository and half would involve returning shipments of empty casks. The fatalities would occur over 24 years and approximately 380 million kilometers (240 million miles) of highway travel. Based on information extrapolated from the U.S. Department of Transportation

Bureau of Transportation Statistics (DIRS 150989-BTS 1998, p. 20), during the same 24-year period about 1 million deaths would be likely to occur in traffic accidents on U.S. highways.

6.2.4.2.2 *Impacts from Accidents – National Mostly Rail Transportation Scenario*

This section discusses the results of the analysis of radiological impacts to populations and maximally exposed individuals and of traffic fatalities that would arise from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the national mostly rail transportation scenario.

DOE used the models and calculations described in Appendix J, Section J.1.4.2.1, to estimate the impacts from rail accidents, and included impacts postulated to occur during the transportation of commercial spent nuclear fuel by legal-weight trucks from six commercial sites that do not have the capability to handle or load large rail casks. The analysis also included the impacts from accidents for heavy-haul truck or barge shipments to nearby railheads from 24 commercial sites that have the capability to load a rail cask but are not served by a railroad. DOE used the models and calculations described in Appendix J to estimate the impacts. Appendix J, Section J.2.4, presents additional information on heavy-haul truck and barge transportation from the 24 commercial sites.

Accident Radiological Impacts for Populations. Based on state-specific accident rates, the total estimated number of rail and truck traffic accidents under the Proposed Action for the mostly rail scenario would be about 10, or about 0.4 per year. The collective radiological dose risk of accidents would be approximately 1 (0.89) person-rem for the population within 80 kilometers (50 miles) along routes for the national mostly rail transportation scenario. This calculated dose risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 1 person-rem would be likely to cause much less than 1 (0.00045) latent cancer fatality.

Radiological risks from accidents for the mostly rail scenario would include impacts associated with about 9,646 railcar shipments (one cask to a railcar) and 1,079 legal-weight truck shipments. National rail transportation of spent nuclear fuel and high-level radioactive waste would account for most of the population dose and risk to the public.

Impacts of Maximum Reasonably Foreseeable Accident Scenario. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario in urbanized areas or rural population zones and under stable and neutral atmospheric conditions. The maximum reasonably foreseeable accident scenario under the mostly rail scenario would involve a release of a fraction of the contents of a rail cask in an urban area under stable meteorological conditions (slowly dispersing atmospheric conditions that would not be exceeded 95 percent of the time), where *atmospheric dispersion* of contaminants would occur more slowly only 5 percent of the time. This accident scenario would have a likelihood of about 2.8 in 10 million per year, and would result in about 5 latent cancer fatalities in the population (Table 6-15). The maximally exposed individual, assumed to be about 330 meters (1,080 feet) from the accident, would receive a dose of about 29 rem. An accident that involved high impact forces or a long-duration fire could reduce the effectiveness of the radiation shielding in a shipping cask. A first responder to this accident could receive a dose of as much as 0.83 rem.

Actual transportation accidents involve collisions of many kinds, such as with other vehicles and roadside objects, involvement in fires and explosions, inundation, and burial. These accidents are caused by a variety of initiating events including human error, mechanical failure, and natural causes such as earthquakes. Accidents occur in many different kinds of places including mountain passes and urban areas, rural freeways in open landscapes, and rail switching yards. Thus, there are as many different kinds of unique initiating events and accident conditions as there are accidents. DOE could not

Table 6-15. Estimated impacts from maximum reasonably foreseeable accident scenario for national mostly rail transportation scenario.

Impact	Urbanized area (stable atmospheric conditions)
Accident probability	0.00000028 per year (about 2.8 in 10 million)
Impacts to populations	
Population dose (person-rem)	9,900
Latent cancer fatalities	5
Impacts to maximally exposed individuals	
Maximally exposed individual dose (rem)	29
Probability of a latent cancer fatality	0.01
Impacts to first responder	
Maximally exposed responder dose (rem)	0.83
Probability of latent cancer fatality	0.0004

practicably attempt to analyze every possible accident that could occur. Instead, DOE analyzed a broad range of accidents, each of which represents a grouping of initiating events and conditions having similar characteristics. For example, the EIS analyzes the impacts of a collection of collision accidents in which a cask would be exposed to impact velocities in the range of 60 to 90 miles per hour (see Appendix J, Section J.1.4.2.1).

In addition, the EIS analyzes a maximum reasonably foreseeable accident in which a collision would not occur but the temperature of a rail cask containing spent nuclear fuel would rise to between 750ºC and 1,000ºC (between 1,400ºF and 1,800ºF) (Section 6.2.4.2). The conditions of the maximum reasonably foreseeable accident analyzed in the EIS envelop conditions reported in newspapers for the Baltimore Tunnel fire (a train derailment and fire that occurred in July 2001 in a tunnel in Baltimore, Maryland). Temperatures in that fire were reported to be as high as 820ºC (1,500ºF) and the fire was reported to have burned for up to 5 days (DIRS 156753-Ettlin 2001, all; DIRS 156754-Rascovar 2001, all).

DOE evaluated other severe accidents. Appendix J, Section J.1.4.2.1, describes these accidents and their potential impacts. The accident conditions for one rail accident (Case 4) could be similar to those from a crash of a commercial jet airliner into a rail cask (DIRS 157210-BSC 2001, all). The consequences of this accident (1,300 person-rem or 0.65 latent cancer fatality) would be less than those for the maximum reasonably foreseeable rail accident described above.

Impacts From Traffic Accidents. The analysis estimated that across the United States approximately 3 (3.1) traffic and train accident fatalities could occur during transportation of spent nuclear fuel and high-level radioactive waste under the national mostly rail transportation scenario. Half of the fatalities would occur during the return of empty casks to commercial and DOE sites. Essentially all of the fatalities would involve train operations; about half would involve highway vehicles hit by trains. There would be about a 12-percent chance of 1 fatality from the 1,079 legal-weight truck shipments of commercial spent nuclear fuel. This fatality could happen during the 24 years of transportation operations involving approximately 77 million kilometers (48 million miles) of railcar travel and 10 million kilometers (6 million miles) of highway travel. On the basis of data presented by the Bureau of Transportation Statistics (DIRS 150989-BTS 1998, p. 20), during the same 24-year period about 1 million people will die in traffic accidents on U.S. highways.

6.2.4.2.3 *Impacts of Acts of Sabotage*

The Nuclear Regulatory Commission has developed a set of rules specifically aimed at protecting the public from harm that could result from sabotage of spent nuclear fuel casks. Known as physical protection and safeguards regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the physical protection and safeguard regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of spent nuclear fuel shipments that could come under control of unauthorized persons

To achieve these objectives, the Nuclear Regulatory Commission physical protection and safeguard rules require:

- Advance notification of each shipment to the Nuclear Regulatory Commission, the states, and Native American governments [proposed rulemaking 10 CFR Parts 71 and 73 (64 *FR* 71331, December 21, 1999)]
- The licensee to have current procedures to cope with safeguards emergencies
- Instructions for escorts on how to determine if a threat exists and how to deal with it
- Maintenance of a communications center to monitor continually the progress of each shipment
- A written log describing the shipment and significant events during the shipment
- Advance arrangements with law enforcement agencies along the route
- Advance route approval by the Nuclear Regulatory Commission
- Avoidance of intermediate stops to the extent practicable
- At least one escort to maintain visual surveillance of the shipment during stops
- Shipment escorts to report status periodically
- Armed escorts in heavily populated areas
- Onboard communications equipment
- Protection of specific shipment information

The cask safety features that provide containment, shielding and thermal protection also provide protection against sabotage. The casks would be massive. The spent nuclear fuel in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

It is not possible to predict whether sabotage events would occur and, if they did, the nature of such events. Nevertheless, DOE examined various accidents, including an aircraft crash into a transportation cask. The consequences of both the maximum reasonably foreseeable accident and the aircraft crash are presented above for the mostly truck and mostly rail transportation scenarios and can provide an approximation of the types of consequences that could occur from a sabotage event. DOE also considered the consequences of a potential successful sabotage attempt on a cask. A study conducted by Sandia National Laboratories (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) estimated the amounts and characteristics of releases of radioactive materials from rail and truck casks subjected to the effects of two different devices.

Devices considered in the Sandia study (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all) included possible devices that might be used in acts of sabotage against shipping casks. (Note: The shield walls of shipping casks for spent nuclear fuel and high-level radioactive waste are similar to the massive layered construction used in armored vehicles such as tanks.) These kinds of devices were demonstrated by the study to be capable of penetrating a cask's shield wall, leading to the dispersal of contaminants to the environment.

The truck cask design selected for analysis was the General Atomics GA-4 Legal-Weight Truck Cask. This cask, which uses uranium for shielding, is a state-of-the-art design recently certified by the Nuclear Regulatory Commission to ship four pressurized-water reactor nuclear fuel assemblies (DIRS 148184-NRC 1998, all). The rail cask design used was based on the conceptual design developed by DOE for the dual-purpose canister system. This design is representative of large rail casks that could be certified for shipping spent nuclear fuel and high-level radioactive waste.

DOE used the RISKIND code (DIRS 101483-Yuan et al. 1995, all) to evaluate the radiological health and safety impacts of the estimated releases of radioactive materials. The analysis used assumptions about the concentrations of radioisotopes in spent nuclear fuel, population densities, and atmospheric conditions (weather) used to evaluate the maximum reasonably foreseeable accidents.

Because it is not possible to forecast the location or the environmental conditions that might exist for acts of sabotage, the analysis determined consequences for urbanized areas (see Appendix J, Section J.1.4.2.1) under neutral (average) weather conditions.

For legal-weight truck shipments, the analysis estimated that a sabotage event occurring in an urbanized area could result in a population dose of 96,000 person-rem. This dose would cause an estimated 48 fatal cancers among the population of exposed individuals. A maximally exposed individual could receive a lifetime committed dose of 110 rem, which would increase the risk of a fatal cancer from about 23 percent from all other causes to about 29 percent.

These estimates exceed those presented in the Draft EIS for two reasons. The analysis for this section assumed that the cask would contain representative (or average hazard) spent nuclear fuel. The analysis in the Draft EIS assumed that the cask would contain typical (or average age) spent nuclear fuel. The amount of radioactivity in representative spent nuclear fuel is about twice that in typical spent nuclear fuel. In addition, the analysis in the Draft EIS used urban area populations reported in the 1990 Census, whereas the analysis for this section used populations projected to 2035. The population estimates used for 2035 are about 40 percent greater than those reported by the 1990 Census. The combined result of these changes is that the estimated consequences of an act of sabotage against a transportation cask in this section are about 3 times those estimated in the Draft EIS.

The consequences estimated for an act of sabotage involving a rail shipment would be less than those estimated for a legal-weight truck shipment. The smaller consequence for the rail shipment would be because less of the radionuclides would be released from a rail transportation cask than from a legal-weight truck transportation cask (DIRS 104918-Luna, Neuhauser, and Vigil 1999, all). For rail shipments, the analysis estimated that a sabotage event in an urbanized area could result in a population dose of 17,000 person-rem. This dose would be likely to cause an estimated 9 fatal cancers among the population of exposed individuals. A maximally exposed individual could receive a lifetime committed dose of 40 rem, which would increase the risk of a fatal cancer from about 23 percent from all other causes to about 25 percent.

Because of the attacks on September 11, 2001, the Department and other agencies are reexamining the protections built into our physical security and safeguards systems for transportation shipments. As dictated by results of this reexamination, DOE would modify its methods and systems as appropriate.

6.2.5 ENVIRONMENTAL JUSTICE

Shipments of spent nuclear fuel and high-level radioactive waste would use the Nation's existing railroads and highways. DOE expects that transportation-related impacts to land use; air quality; hydrology; biological resources and soils; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would be small. In addition, as described in the preceding sections, incident-free transportation and the risks from transportation accidents (the maximum reasonably foreseeable accident scenario would have about 3 chances in 10 million of occurring per year) would not present a large health or safety risk to the population as a whole, or to workers or individuals along national transportation routes. The low effect on the population as a whole also would be likely for any segment of the population, including minorities, low-income groups, and members of Native American tribes.

A previous DOE analysis of the potential for environmental justice concerns from the transportation of DOE spent nuclear fuel to the Idaho National Engineering and Environmental Laboratory (DIRS 101802-DOE 1995, Volume 1, pp. L-2 and L-36) also concluded that impacts to minority and low-income populations and to populations of American Indians in Idaho would not be disproportionately high and adverse. As part of that analysis, DOE consulted with the Shoshone Bannock Tribe to analyze impacts to tribe members because the shipments in question would cross the Fort Hall Reservation. The analysis (DIRS 101802-DOE 1995, Volume 3, Part A, p. 3-32) concluded that risks to the health and safety of the potentially affected tribal population in Idaho from incident-free transportation and from accidents would be very low.

The EIS analyzes potential public health effects of both routine (incident-free) transportation of radioactive materials and transportation accidents involving radioactive materials. First, regarding routine transportation, the EIS considers air emissions and doses from exposure to radioactive materials during transport. The EIS estimates the impact from air emissions to be 1 emissions-related fatality. The EIS also estimates that the 24-year national transportation campaign would cause fewer than about 3 latent cancer fatalities among the public under the mostly legal-weight truck scenario and fewer under the preferred mostly rail scenario. Although many people would be exposed nationwide over a long campaign, the radiation dose to any exposed individual would be very low. In this context, DOE does not consider such impacts to be high. Because DOE does not know of a plausible mechanism under these circumstances whereby low-income or minority populations could incur high and adverse impacts when the general public would not, the Department believes there could be no disproportionately high and adverse impacts on low-income or minority populations.

The EIS estimates the number of people in the general public who could be killed by accidents involving transportation of spent fuel and high-level radioactive waste. The two mechanisms for such impacts are bodily trauma from collisions or exposure to radioactivity that would be released if a sufficiently severe accident occurred. The analysis estimated that the 24-year national campaign would cause fewer than 5 fatalities among the general public from trauma sustained in collisions with vehicles carrying spent nuclear fuel or high-level radioactive waste. In this context, DOE does not consider such impacts to be high. Again, DOE does not know of a plausible mechanism under these circumstances whereby low-income or minority populations could incur high and adverse impacts when the general public would not.

Only a severe accident that resulted in a considerable release of radioactive material could cause high and adverse health effects to the affected population. Because the risk of these high and adverse consequences applies to the entire population along all transportation routes, it would not apply disproportionately to any minority or low-income population.

Based on the analysis of incident-free transportation and transportation accidents in this EIS and the results of a transportation analysis conducted by DOE in a previous programmatic EIS, and the fact that

DOE has identified no subsection of the population that would be disproportionately affected by transportation related to the Proposed Action, DOE has concluded that no disproportionately high and adverse impacts would be likely on minority or low-income populations from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

Section 6.3.4 discusses environmental justice in relation to transportation in Nevada. Chapter 4, Section 4.1.13.4, contains a discussion of a Native American perspective on the Proposed Action.

6.3 Nevada Transportation

The analysis of impacts from national transportation includes those from transportation activities in the State of Nevada. This section discusses Nevada transportation impacts separately to ensure that the impacts of alternative transportation modes in Nevada are apparent. Spent nuclear fuel and high-level radioactive waste shipped to the repository by legal-weight truck would continue in the same vehicles to the Yucca Mountain site. Material that traveled by rail would either continue to the repository on a newly constructed branch rail line or transfer to heavy-haul trucks at an intermodal transfer station that DOE would build in Nevada for shipment on existing highways that could require upgrades. Selection of a specific rail alignment within a corridor, or the specific location of an intermodal transfer station or the need to upgrade the associated heavy-haul truck routes, would require additional field surveys, environmental and engineering analysis, state, local, and Native American Tribal government consultation, and National Environmental Policy Act reviews.

The transportation analysis in the EIS treats the candidate legal-weight truck routes, rail corridors, and heavy-haul truck routes as current analysis tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice *(would)* because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

This section describes potential impacts of three transportation scenarios and their respective implementing alternatives. The three transportation scenarios are (1) mostly legal-weight truck (corresponding to that portion of the national impacts that would occur in Nevada), (2) mostly rail, and (3) mostly heavy-haul truck.

The mostly legal-weight truck scenario does not include implementing alternatives. Under this scenario, highway shipments would be restricted to specific routes that satisfy the regulations of the U.S. Department of Transportation (49 CFR Part 397). Because the State of Nevada has not designated alternative preferred routes, only one combination of routes for legal-weight truck shipments would satisfy U.S. Department of Transportation routing regulations (I-15 to U.S. Highway 95 to Yucca Mountain). This scenario assumes that over 24 years approximately 300 shipments of naval spent nuclear fuel would arrive in Nevada by rail from the Idaho National Engineering and Environmental Laboratory and that heavy-haul trucks would transport them to the repository from a railhead.

The mostly rail scenario has five implementing alternatives, each of which includes a corridor with variations for a branch rail line in Nevada. Each implementing alternative includes the construction and operation of a rail line. These alternatives would include about 1,079 legal-weight truck shipments (about 45 per year) from 6 commercial sites that, while operational, would not have the capability to load rail casks.

The mostly heavy-haul truck scenario has implementing alternatives for five different routes on existing Nevada highways. The highways would have to be upgraded to enable heavy-haul trucks routinely to transport rail casks containing spent nuclear fuel and high-level radioactive waste from an intermodal transfer station to the repository. Each heavy-haul truck implementing alternative includes the

DOE has identified no subsection of the population that would be disproportionately affected by transportation related to the Proposed Action, DOE has concluded that no disproportionately high and adverse impacts would be likely on minority or low-income populations from the national transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain.

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The transportation analysis in the EIS treats the candidate legal-weight truck routes, rail corridors, and heavy-haul truck routes as current analysis tools and refers to them in the present tense. The EIS refers to impacts associated with these alternatives in the conditional voice *(would)* because they would not occur unless DOE proceeded with the Proposed Action. This convention is applied whenever the EIS discusses the transportation implementing alternatives.

This section describes potential impacts of three transportation scenarios and their respective implementing alternatives. The three transportation scenarios are (1) mostly legal-weight truck (corresponding to that portion of the national impacts that would occur in Nevada), (2) mostly rail, and (3) mostly heavy-haul truck.

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The mostly rail scenario has five implementing alternatives, each of which includes a corridor with variations for a branch rail line in Nevada. Each implementing alternative includes the construction and operation of a rail line. These alternatives would include about 1,079 legal-weight truck shipments (about 45 per year) from 6 commercial sites that, while operational, would not have the capability to load rail casks.

The mostly heavy-haul truck scenario has implementing alternatives for five different routes on existing Nevada highways. The highways would have to be upgraded to enable heavy-haul trucks routinely to transport rail casks containing spent nuclear fuel and high-level radioactive waste from an intermodal transfer station to the repository. Each heavy-haul truck implementing alternative includes the construction and operation of an intermodal transfer station that DOE would use to transfer loaded rail casks from railcars to heavy-haul trucks and empty rail casks from the trucks to railcars. The analysis considered three potential intermodal transfer station locations. Each heavy-haul implementing alternative would also include 1,079 legal-weight truck shipments over 24 years from the 6 commercial sites that, while operational, would not have the capability to load rail casks.

Chapter 2, Section 2.1.3.3, contains detailed descriptions of the transportation scenarios and implementing alternatives in Nevada. Sections 6.3.1 through 6.3.3 discuss potential impacts for the three Nevada transportation scenarios. Section 6.3.1 discusses potential environmental impacts that could occur in Nevada for the national mostly legal-weight truck scenario. Section 6.3.2 discusses potential environmental impacts for each of the five Nevada rail transportation implementing alternatives, including those from the construction and operation of a branch rail line, and the impacts of 1,079 legal-weight truck shipments over 24 years. Section 6.3.3 discusses potential impacts of each of the five Nevada heavy-haul truck transportation implementing alternatives, including upgrading Nevada highways, the associated activities of constructing and operating an intermodal transfer station, and the impacts of 1,079 legal-weight truck shipments over the 24 years of operations. Appendix J, Section J.3.6, presents an analysis of impacts of transporting people and materials that would be necessary to implement the Proposed Action. Appendix J also discusses the methods used to analyze impacts for the 12 resource areas.

The EIS analysis evaluated potential impacts that would occur in Nevada from the construction and operation of a branch rail line or from upgrades to highways and construction and operation of an intermodal transfer station for the following environmental resource areas: land use and ownership; air quality; hydrology (surface water and groundwater); biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; waste management; and environmental justice. The following paragraphs describe the methods used to evaluate potential impacts to these resource areas for each of the three Nevada transportation scenarios—legal-weight truck, rail, and heavy-haul truck—and their applicable implementing alternatives.

Tables 6-16 and 6-17 compare the impacts of the Nevada rail and heavy-haul implementing alternatives, respectively, along with the impacts in Nevada under the mostly legal-weight truck scenario. The comparisons in the tables show that potential health and safety impacts to the public and workers in Nevada would be small for both the mostly legal-weight truck and mostly rail transportation scenarios. In addition, the tables illustrate that impacts would be similar among the 10 rail and heavy-haul truck implementing alternatives. The radiological impacts of incident-free transportation in the State for any of the 10 implementing alternatives or for the mostly legal-weight truck scenario would be small for both the public and workers. The radiological impact from 24 years of transportation would range from 0.0009 to 0.17 latent cancer fatality in the population along routes. The radiological impact to transportation workers from 24 years of operations would range from 0.28 to 0.75 latent cancer fatality for the mostly rail scenario with a Valley Modified Corridor branch rail line and the mostly legal-weight truck scenario, respectively.

As many as 5 latent cancer fatalities could occur from a maximum reasonably foreseeable accident involving a rail shipment. Less than 1 (0.5) latent cancer fatality would occur as the result of a severe truck accident with a similar probability. These accidents would have a chance of occurring nationally of less than 3 in 10 million per year. Because only a small part of each national route is in Nevada, the rate of occurrence in the State would be much less than that nationally. Accidents that would be more likely would have lesser consequences.

Traffic fatalities in Nevada and fatalities caused by the effects of vehicle emissions would be greater for the mostly rail transportation scenario than for the mostly legal-weight truck scenario. The estimate of

Table 6-16. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 1 of 2).

Impact	Mostly rail with branch rail					Mostly legal-weight truck
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	
Corridor length (kilometers)	512 - 553	514 - 544	344 - 382	181 - 204	159 - 163	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	18 - 20	19 - 20	13 - 14	9.2 - 10	5 - 5.2	0
Private land (square kilometers)	0.9 - 2.5	7.3 - 15	0.8 - 1.1	0.1 - 3.5	0 - 0.18	0
Nellis Air Force Range land (square kilometers)	0 - 11	0 - 11	22	0	3.6 - 7.5	0
Tribal	0 - 1.6	0 - 1.6	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Areas in attainment of air quality standards - branch rail line not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - branch rail line not a significant source of pollution	Clark County is in nonattainment of air quality standards for PM_{10} - branch rail line construction could be a significant source of pollution[b]	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Surface water resources along route	5	6	3	0	0	NA[d]
Flood zones	9	11	At least 3	7	2	NA
Groundwater						
Water use (acre-feet)[c]	710	660	480	410	320	0
Water use (number of wells)	64	67	43	23	20	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological or historical resources. Route passes close to the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Moderate	Low	Moderate	Moderate	Moderate	Low
Utilities and resources						
Diesel (million liters)[e]	45	41	36	30	14	Very low
Gasoline (thousand liters)	940	840	680	570	280	
Steel (thousand metric tons)[f]	78	75	52	29	23	0
Concrete (thousand metric tons)[g]	460	420	310	170	130	0

Table 6-16. Comparison of impacts for Nevada rail implementing alternatives and for legal-weight truck shipments (page 2 of 2).

Impact	Mostly rail with branch rail					Mostly legal-weight truck
	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified	
Aesthetics	Very low	Very low	Very low	Potential small area of conflict	Very low	None
Socioeconomics						
New jobs (percent of workforce in affected counties	840 (< 1% - 3.2%)	780 (< 1%)	650 (<1% - 2.3%)	530 (< 1%)	250 (< 1%)	Very low
Peak real disposable income (million dollars)	24	21	19	15	7	Very low
Peak incremental Gross Regional Product (million dollars)	40	36	31	26	13	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	220	200	180	150	110	NA
Lost workday cases	110	100	90	80	60	NA
Fatalities	0.43	0.41	0.38	0.3	0.25	NA
Collective dose (person-rem [LCFs])						
Workers	850 [0.34]	980 [0.39]	740 [0.3]	760 [0.3]	710 [0.28]	1,900 [0.75]
Public	19 [0.009]	38 [0.019]	50 [0.025]	130 [0.06]	23 [0.012]	340 [0.17]
Fatalities from vehicle emissions	0.25	0.25	0.2	0.23	0.13	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	1.9	1.8	1.5	1.2	0.9	NA
SNF[h] and HLW[i] shipping	0.07	0.09	0.05	0.06	0.05	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.002	0.003	0.002	0.007	0.002	0.053
Latent cancer fatalities	0.0000009	0.0000013	0.0000009	0.0000036	0.000001	0.000026
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. Convert square kilometers to acres, multiply by 247.1.
b. Conformity determination could be required (see Chapter 6, Sections 6.3.2.1 and 6.3.2.2.5).
c. To convert acre-feet to gallons, multiply by 325,850.1.
d. NA = not applicable.
e. To convert liters to gallons, multiply by 0.26418.
f. To convert metric tons to tons, multiply by 1.1023.
g. To convert cubic feet to cubic meters, multiply by 0.028317.
h. SNF = spent nuclear fuel.
i. HLW = high-level radioactive waste.

Table 6-17. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 1 of 3).

Impact	Mostly rail with heavy-haul truck: Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Corridor length (kilometers)	530	280	380	190	180	230 - 270
Land use and ownership						
Disturbed land (square kilometers)[a]	3.4	1.3	2.1	0.63	0.63	0
Private land (square kilometers)	0	0	0	0	0	0
Nellis Air Force Range land (square kilometers)	0	0	0	0	0	0
Air quality						
PM_{10} and carbon monoxide (construction and operations)	Areas in attainment of air quality standards - not a significant source of pollution	Areas in attainment of air quality standards - not a significant source of pollution	Clark County is in nonattainment of air quality standards - heavy-haul route construction could be a significant source of pollution[b]	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Except in Clark County, areas in attainment of air quality standards - not a significant source of pollution	Not a significant source of pollution
Hydrology						
Surface water	Low	Low	Low	Low	Low	None
Groundwater						
Water use (acre-feet)c	100	60	44	8	8	0
Water use (number of wells)	16	5	7	Truck water	Truck water	0
Biological resources and soils	Low	Low	Low	Low	Low	Very low
Cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources	None identified to archaeological, historical, or cultural resources; route near Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; route passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	None identified to archaeological, historical, or cultural resources; IMT[d] and route near the Moapa Indian Reservation and passes across 1.6-kilometer (1-mile) corner of the Las Vegas Paiute Indian Reservation	Since shipments would use existing highways, none to archaeological or historical resources. Shipments from the northeast would pass through the Moapa Indian Reservation. All shipments would pass through the Las Vegas Paiute Indian Reservation
Noise	Low	Low	Low	Low	Low	Low
Utilities and resources						
Diesel (million liters)[e]	13	4.7	5.5	1.7	1.6	Very low
Steel (metric tons)[f]	49	14	21	2.3	2.3	0
Concrete (thousand metric tons)[g]	1.8	0.5	0.8	0.1	0.1	0
Aesthetics	Some potential near Caliente	Some potential near Caliente	Some potential near Caliente	Very low	Very low	None

Table 6-17. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 2 of 3).

Impact	Mostly rail with heavy-haul truck					Mostly legal-weight truck
	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	
Socioeconomics						
New jobs (percent of workforce in affected counties)	860 (< 1% - 3.3%)	750 (< 1% - 4.9%)	590 - 1,980 (< 1% - 3.3%)	630 - 3,050 (< 1%)	490 - 1,880 (< 1%)	Very low
Peak real disposable personal income (million dollars)	27	22	19 - 65	21 - 97	16 - 62	Very low
Peak incremental Gross Regional Product (million dollars)	45	40	33 - 104	36 - 153	29 - 100	Very low
Waste management	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Limited quantity	Very low
Environmental justice (disproportionately high and adverse impacts)	None	None	None	None	None	None
Incident-free health and safety						
Industrial hazards						
Total recordable incidents	310	270	260	150	150	NA[h]
Lost workday cases	160	140	140	80	80	NA
Fatalities	0.72	0.68	0.63	0.37	0.37	NA
Collective dose (person-rem [LCFs])						
Workers	1,600 [0.65]	1,200 [0.50]	1,400 [0.56]	1,200 [0.48]	1,100 [0.46]	1,900 [0.75]
Public	76 [0.038]	61 [0.030]	220 [0.11]	300 [0.15]	160 [0.08]	340 [0.17]
Fatalities from vehicle emissions	0.47	0.32	0.46	0.42	0.29	0.086
Accident impacts, nonradiological traffic						
Construction and operations workforce	3.5	2.4	3.0	1.7	1.7	NA
SNF[i] and HLW[j] shipping	0.6	0.33	0.43	0.25	0.23	0.49
Accident impacts, radiological						
Radiological accident risk						
Person-rem	0.01	0.002	0.056	0.12	0.056	0.053
Latent cancer fatalities	0.0000051	0.000001	0.000028	0.00006	0.000028	0.000026

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Table 6-17. Comparison of impacts for Nevada heavy-haul truck implementing alternatives and for legal-weight truck shipments (page 3 of 3).

	Mostly rail with heavy-haul truck					
Impact	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Sloan/Jean	Apex/Dry Lake	Mostly legal-weight truck
Maximum reasonably foreseeable accident						
Maximally exposed individual (rem)	29	29	29	29	29	3
Individual latent cancer fatality probability	0.014	0.014	0.014	0.014	0.014	0.0015
Collective dose (person-rem)	9,900	9,900	9,900	9,900	9,900	1,100
Latent cancer fatalities	4.9	4.9	4.9	4.9	4.9	0.55

a. To convert square kilometers to acres, multiply by 247.1.
b. Conformity determination could be required (see Chapter 6, Sections 6.3.3.1 and 6.3.3.2.3).
c. To convert acre-feet to gallons, multiply by 325,850.1.
d. IMT = intermodal transfer.
e. To convert liters to gallons, multiply by 0.26418.
f. To convert metric tons to tons, multiply by 1.1023.
g. To convert cubic feet to cubic meters, multiply by 0.028317.
h. NA = not applicable.
i. SNF = spent nuclear fuel.
j. HLW = high-level radioactive waste.

traffic facilities includes those that could occur when workers associated with highway or railroad construction commute to and from their work site. The estimates also include traffic fatalities that could result from highway accidents in delivering construction materials used to construct a branch rail line or upgrade highways and construct an intermodal transfer station. Construction and operations activities to transport spent nuclear fuel and high-level radioactive waste in Nevada could result in less than 1 to 5 traffic fatalities (0.5 or a 50 percent chance of 1 fatality to about 4.6). The fewest number of traffic fatalities would occur under the mostly legal-weight truck scenario, principally because the scenario would not require workers associated with construction and operations for Nevada rail implementing alternatives.

Because the trucks would use existing highways and be less than 1 percent of other commercial truck traffic on these highways, measurable impacts would not occur in environmental resource areas other than health and safety in Nevada for mostly legal-weight truck transportation. In contrast, the mostly rail scenario, or any other mix of rail and truck transportation that included a large amount of rail transportation, would require DOE to construct and operate a branch rail line in one of the five candidate rail corridors or construct and operate an intermodal transfer station and work with the State to upgrade highways to use one of the candidate routes for heavy-haul trucks. As a consequence, for the DOE-preferred mostly rail scenario, there would be impacts in Nevada to land use, air quality, hydrological resources, biological resources and soils, cultural resources, socioeconomics, aesthetics, noise and vibration, and waste management. Because it would require acquisition of a large area of land in the State, disturbance of land areas not previously disturbed, and the greatest amount of construction activity, construction of a branch rail line would have the potential to cause greater impacts in all resource areas except health and safety than would construction of an intermodal transfer station and highway upgrades. However, all five of the candidate rail corridors pass through sparsely populated or uninhabited areas of Nevada. Therefore, trains on a branch rail line after construction would have less day-to-day impact on daily life in communities than would heavy-haul trucks, which would share highways with other vehicles. Operational impacts (encompassing those impacts that would occur after construction of a branch rail line or highway upgrade for heavy-haul trucks) would be small in all resource areas for all ten of the rail and heavy-haul truck implementing alternatives.

In general, the longest rail corridor (Caliente) would have the largest potential for impacts, but there are exceptions. For example, construction of a branch rail line in the Valley Modified Corridor, which is the shortest of the five, could affect the Clean Air Act attainment objectives of Clark County for PM_{10} and carbon monoxide, for which the Las Vegas Valley air basin is currently in nonattainment. In addition, both the Jean and Valley Modified Corridors pass through desert tortoise habitat over their entire length and over a distance greater than the three longer corridors. The Wilson Pass Option of the Jean Corridor would require construction of a branch rail line in areas classified by the Bureau of Land Management as Class II for visual resource management. Construction and use of a branch rail line in these areas could be in conflict with Bureau Visual Resource Management guidelines. All five corridors and the Caliente/Chalk Mountain heavy-haul route have potential land-use conflicts at some points along their lengths. The ability of DOE to avoid or mitigate these conflicts varies among the implementing alternatives.

Construction or upgrading of the longest heavy-haul route (Caliente) would lead to the greatest potential for impacts, with some exceptions. For example, although most impacts of using an Apex/Dry Lake heavy-haul truck implementing alternative would be less than those of using a Caliente heavy-haul truck implementing alternative, the potential for impacts to air quality in the Las Vegas Valley air basin and impacts on traffic flow in the Las Vegas metropolitan area are greater for the Apex/Dry Lake route than for the Caliente route. In addition, socioeconomic impacts in Lincoln County, although small, would be greatest for construction and use of a Caliente/Chalk Mountain heavy-haul route. Furthermore, while health and safety impacts in small communities in Nevada, while small, would be greatest for a Caliente heavy-haul route, the shortest route would use the Las Vegas Beltway, which would pass through a highly populated commercial and residential area of North Las Vegas.

Each rail corridor and heavy-haul route could pass near or through areas having high percentages of minority or low-income populations. However, DOE has determined that there would be no environmental justice concerns for any of the proposed routes for heavy-haul trucks or corridors for a potential branch rail line because no potential impact to these populations would be both high and adverse.

LAND USE AND OWNERSHIP

DOE determined that information useful for an evaluation of land-use and ownership impacts should identify the current ownership of the land that its activities could disturb, and the present and anticipated future uses of the land. The region of influence for land-use and ownership impacts was defined as land areas that would be disturbed or whose ownership or use would change as a result of the construction and use of a branch rail line, intermodal transfer station, midroute stopover for heavy-haul trucks, and an alternative truck route near Beatty, Nevada.

AIR QUALITY

The evaluation of impacts to air quality considered potential emissions of criteria pollutants [nitrogen dioxide, sulfur dioxide, carbon monoxide, particulates with aerodynamic diameters of less than 10 micrometers (PM_{10})], lead, and ozone, the percentage of applicable standards and limits, and the potential for releases of these pollutants in the Las Vegas Valley. The region of influence for the air quality analysis included (1) the Las Vegas Valley for implementing alternatives that could contribute to the levels of carbon monoxide and PM_{10}, which are already in nonattainment of Clean Air Act standards (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54), during the construction and operation of a branch rail line or highway for heavy-haul trucks, and (2) the atmosphere in the vicinity of the sources of criteria pollutants that transportation-related construction and operation activities would emit. The evaluation included a conformity review for emissions to the Las Vegas Valley air basin that would result from the Proposed Action.

HYDROLOGY

The analysis evaluated surface-water and groundwater impacts separately. The attributes used to assess surface-water impacts were the potential for introduction and movement of contaminants, potential for changes to runoff and infiltration rates, alterations in natural drainage, and potential for flooding or dredging and filling actions to aggravate or worsen any of these conditions. The region of influence for surface-water impacts included areas near construction activities, areas that would be affected by permanent changes in flow, and areas downstream of construction.

The analysis addressed the potential for a change in infiltration rates that could affect groundwater, the potential for introduction of contaminants, the availability for use for construction, the potential for changing flow patterns and, if available, the potential that such use would affect other users. The region of influence for this analysis included groundwater reservoirs.

BIOLOGICAL RESOURCES AND SOILS

The evaluation of impacts to biological resources considered the potential for conflicts with areas of critical environmental concern; special status species (plants and animals), including their habitats; and jurisdictional waters of the United States, including wetlands and riparian areas. The evaluation also considered the potential for impacts to migratory patterns and populations of big game animals. The region of influence for this analysis included the following:

- Habitat, including jurisdictional waters of the United States, including wetlands and riparian areas

- Migratory ranges of big game animals that could be affected by the presence of a branch rail line

DOE identified known biological resources within 5 kilometers (3 miles) of each rail corridor or variation. Resources were categorized based on proximity to the railroad—that is, inside the 400-meter-(0.25-mile)-wide corridor or outside the corridor but within 5 kilometers of the railroad. A railroad would be unlikely to influence some resources outside the corridor, such as populations of sensitive plant species or springs. It could influence other resources, especially those involving large game animals, horses, or burros, because they could traverse the distance to the railroad easily.

DOE identified soils classified as Easily Erodible, Prime Farmland, Shrink-Swell, Unstable Fill, or Blowing Soil along each route. No Prime Farmland was identified for any route. Although these soil characteristics would principally influence construction, they could influence the amount of land disturbed inside and outside the corridor and the local environment during construction, such as temporary increases in sediment loads in nearby waterways or springs, or entrainment of blowing soil.

The analysis assessed soil impacts to determine the potential to increase erosion rates by water or wind. The region of influence for the analysis of soil impacts included areas where construction would take place and downwind or downgradient areas that would be affected by eroded soil.

CULTURAL RESOURCES

The evaluation of impacts on cultural resources considered the potential for disrupting, or modifying the character of, archaeological or historic sites, artifacts, and other cultural resources, such as traditional cultural properties and cultural landscapes.

The specific region of influence for the *direct impact* analysis included the lands in the 400-meter (0.25-mile)-wide rail corridors, lands within existing highway rights-of-way that would be upgraded for heavy-haul truck use, and sites where an intermodal transfer station could be constructed and operated. The analysis assessed the potential for impacts to areas adjacent to a proposed rail corridor, such as landscapes traditional to American Indians or other historic cultural landscapes.

OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

The analysis of impacts to occupational and public health and safety from transportation-related activities in Nevada used the same methods, assumptions, attributes, and regions of influence used for the analysis of impacts of national transportation of spent nuclear fuel and high-level radioactive waste. However, it used the rail and highway accident rates reported for the State of Nevada (DIRS 103455-Saricks and Tompkins 1999, Table 4). The analysis also considered the daily average nonresident population in the Las Vegas metropolitan area for routes that pass through the Las Vegas metropolitan area.

In addition, the analysis included potential impacts from industrial hazards to Nevada workers from constructing and operating a branch rail line, upgrading highways for use by heavy-haul trucks, and constructing and operating an intermodal transfer station. The region of influence for the analysis included branch rail line and highway construction work sites and highways that workers and other construction-related vehicle traffic would use. The analysis considered potential radiological impacts from intermodal transfer station operations.

In addition, the analysis estimated doses to potential maximally exposed individuals in Nevada communities through which truck or rail shipments could travel. Appendix J, Section J.1.3.2.2 discusses the basis for these estimates. The health and safety portions of Sections 6.3.2.1 and 6.3.3.1 describe the potential impacts to maximally exposed individuals in Nevada.

SOCIOECONOMICS

The analysis of transportation-related socioeconomic impacts considered changes in annual levels of employment, population, housing, and schools, in addition to the economic measures of real disposable income, Gross Regional Product, and state and local government expenditures based on analyses DOE conducted using the Regional Economic Models, Inc. model (DIRS 148193-REMI 1999, all). The region of influence for the analysis included Clark, Lincoln, and Nye Counties. The other Nevada counties were included collectively in the Rest of Nevada analysis. The analysis considered impacts that would occur during construction and operation of the various transportation implementing alternatives.

The analysis expressed socioeconomic impacts as a percentage change, which it calculated by comparing the derived increase or decrease in a given socioeconomic parameter to the estimated baseline value for:

- Each county in the region of influence (Clark, Nye, and Lincoln), the Rest of Nevada, and the State of Nevada.
- The year.
- Economic measures (employment, population, real disposable income, Gross Regional Product, and State and local government spending).

Chapter 3, Section 3.1.7 lists the baseline values of each economic measure.

DOE has described the socioeconomic measures on a peak year basis for constructing a branch rail line, upgrading of highways, or constructing an intermodal transfer station and on an average basis for transportation operations. The Department used peak values and their impacts for construction because impacts would tend to be concentrated in 1 or 2 years. DOE used average values for the period of transportation operations as a more meaningful presentation of the data. Impacts, as a percentage of the baselines, would tend to be relatively stable over the 24 years of transportation operations for the Proposed Action.

In light of public comments received on the Draft EIS concerning perception-based and stigma-related impacts, DOE examined relevant studies and literature on perceived risk and stigmatization of communities to determine whether the state of the science in predicting future behavior based on perceptions had advanced sufficiently since scoping to allow DOE to quantify the impact of public risk perception on economic development or property values in potentially affected communities. Of particular interest were those scientific and social studies carried out in the past few years that directly relate to either Yucca Mountain or to DOE actions such as the transportation of foreign research reactor spent nuclear fuel. DOE also reevaluated the conclusions of previous literature reviews such as those conducted by the Nuclear Waste Technical Review Board and the State of Nevada, among others. DOE has concluded that:

- While in some instances risk perceptions could result in adverse impacts on portions of a local economy, there are no reliable methods whereby such impacts could be predicted with any degree of certainty
- Much of the uncertainty is irreducible, and
- Based on a qualitative analysis, adverse impacts from perceptions of risk would be unlikely or relatively small.

While stigmatization of southern Nevada can be envisioned under some scenarios, it is not inevitable or numerically predictable. Any such stigmatization would likely be an aftereffect of unpredictable future events, such as serious accidents, which may not occur. As a consequence, DOE did not attempt to quantify any potential for impacts from risk perceptions or stigma in this Final EIS. Chapter 2, Section 2.5.4 contains further detail.

NOISE AND VIBRATION

Nevada does not have a noise code, so the analysis used daytime and nighttime noise standards adopted by Washington State (Washington Administrative Code 173-58-040 to 173-60-040) for residential and commercial areas as benchmarks and for establishing the region of influence for potential impacts. DOE used these benchmarks [60 dBA for residential use (nighttime reduction to 50 dBA), 65 dBA for light commercial, and 70 dBA for industrial zones] to evaluate the impacts of noise from construction and operational activities for receptors in the region of influence near transportation facilities and corridors. Noise levels in areas and communities outside the region of influence were not addressed. To analyze the potential for community noise impacts, DOE established the region of influence as 1,000 meters (about 0.63 mile) based on the residential nighttime benchmark. This is the approximate distance from a railroad or highway at which the sound levels from passing trains or traffic would fall below 50 dBA. The distances for noise levels from a railroad to fall below 50 dBA (nighttime residential noise standard) and 60 dBA (daytime residential guideline) are 1,000 meters and 450 meters (about 0.25 mile), respectively.

DOE also defined a region of influence for locations where there would be a potential for impacts to solitude. These locations would include sites of special interest to Native Americans, where DOE assumes a sound level of 20 dBA would be necessary for solitude. This distance from passing trains or traffic would be about 6,000 meters (3.7 miles). To provide some perspective on the potential severity of noise impacts, the analysis estimated the population within 2 kilometers (about 1.3 miles) of each proposed rail corridor and heavy-haul truck route.

In addition to noise standards, the analysis assessed the frequency at which transportation noise from construction or operation of a transportation route could lead to complaints. It considered the proximity of transportation routes to centers of population and the frequency of shipments.

The analysis also considered potential effects of ground vibration from trains and heavy-haul trucks. In general, the operation of trains and trucks does not create vibration levels of an intensity that can damage most buildings unless they are very close to the rail line or highway (DIRS 155547-HMMH 1995, p. 8-3). Because trucks run on inflated tires, ground vibration is greatly reduced and the only situation that can produce potentially damaging ground vibration occurs when the vehicle strikes a bump or hole in the road. The intensity of the vibration depends on the size of the bump, speed and weight of the vehicle, and geology. Ground vibration can be disturbing to people, particularly at night, and it can adversely affect vibration-sensitive activities such as semiconductor manufacturing, operation of electron microscopes, and other activities. The U.S. Department of Transportation has proposed critical distances for the evaluation of ground vibration (DIRS 155547-HMMH 1995, pp. 9-4 and 8-3). These are expressed in feet and are based on the *decibel* scale for vibration (VdB) of root-mean-square (in relation to a microinch per second base). (A microinch is one-millionth of an inch or 0.0000025 centimeter; this measurement is used in applications that require extremely tight tolerances.) The endpoint for sensitive buildings is 65 VdB and the corresponding critical distance is 600 feet (about 180 meters). For human annoyance, the critical distance is based on 72 VdB and corresponds to 200 feet (about 61 meters). The estimated critical distance for structural damage due to the operation of unit coal trains is 100 meters (about 330 feet) based on a peak particle velocity measurement of 0.1 inch per second. Trains traveling to Yucca Mountain would include two locomotives and probably no more than 10 cars. The U.S. Department of Transportation (DIRS 155547-HMMH 1995, all) has proposed a structure protection criterion of

0.12-inch-per-second peak particle velocity. A corresponding region of influence is 100 meters (about 330 feet). High levels of ground vibration can be managed in sensitive areas by reducing the speed of the trains, a factor that usually occurs for safety purposes. Most of the candidate rail corridors to Yucca Mountain are in open or isolated areas with few structures; as a consequence, the chance of building damage from the operation of trains would be very small.

The analysis of impacts on biological resources considered the effects of environmental noise from trains and trucks on animals. There are no standards or regulatory measures for such impacts.

AESTHETICS

The analysis of potential impacts on aesthetic resources considered Bureau of Land Management ratings for land areas (DIRS 101505-BLM 1986, all). The regions of influence used in the analysis included the landscapes along the potential rail corridors and highway routes and near possible locations of intermodal transfer stations with aesthetic quality that construction and operations could affect.

The analysis of impacts was based on visual sensitivity ratings of viewsheds in Nevada and the Bureau of Land Management Visual Resource Management System objectives. It established ratings for scenery based on the number and types of users, public interest in the area, and adjacent land uses. The ratings are based on the scenic quality classes in the Bureau of Land Management Visual Resource Management System (DIRS 101505-BLM 1986, all).

UTILITIES, ENERGY, AND MATERIALS

The attributes used to assess impacts to utilities, energy, and materials included the requirements for electric power, fossil fuel for construction, and key consumable construction materials. The analysis compared needs to available capacity. The region of influence included the local, regional, and national supply infrastructure that would have to satisfy the needs.

WASTE MANAGEMENT

Evaluations of impacts of waste management considered the nonhazardous industrial, sanitary, hazardous, and low-level radioactive wastes that the Proposed Action would generate. The region of influence included construction areas and camps and facilities that would support transportation operations such as locomotive and railcar maintenance facilities.

ENVIRONMENTAL JUSTICE

DOE performs environmental justice analyses to identify whether any high and adverse impacts would fall disproportionately on minority and low-income populations. There would be a potential for environmental justice concerns if the following occurred:

- *Disproportionately high and adverse human health effects to minority or low-income populations:* Adverse health effects would be risks and rates of exposure that could result in latent cancer fatalities and other fatal or nonfatal adverse impacts to human health. Disproportionately high and adverse human health effects occur when the risk or rate for a minority or low-income population from exposure to a potentially large environmental hazard appreciably exceeds or is likely to appreciably exceed the risk to the general population and, where available, to another appropriate comparison group (DIRS 103162-CEQ 1997, all).

- *Disproportionately high and adverse environmental impacts to minority or low-income populations:* An adverse environmental impact is one that is unacceptable or above generally accepted norms. A disproportionately high impact is an impact (or the risk of an impact) to a low-income or minority community that significantly exceeds the corresponding impact to the larger community (DIRS 103162-CEQ 1997, all).

The approach to environmental justice analysis first brings together the results of analyses from different technical disciplines that focus on consequences to certain resources, such as air, land use, socioeconomics, air quality, noise, and cultural resources, that could affect human health or the environment. The environmental justice approach considers assessments from these disciplines that identify potential impacts on the general population. Second, based on available information, the approach assesses if there are unique exposure pathways, sensitivities, or cultural practices that would result in high and adverse impacts on minority and low-income populations. If potential impacts identified under either assessment would be high and adverse, the approach then compares the impacts on minority and low-income populations to those on the general population to determine if any high and adverse impacts would fall disproportionately on minority and low-income populations. In other words, if high and adverse impacts on a minority or low-income population would not appreciably exceed the same type of impacts on the general population, disproportionately high and adverse impacts would be unlikely. In making these determinations, DOE considers geographic areas that contain high percentages of minority or low-income populations as reported by the Bureau of the Census.

The EIS definition of a minority population is in accordance with the basic racial and ethnic categories reported by the Bureau of the Census. A minority population is one in which the percent of the total population comprising a racial or ethnic minority is meaningfully greater than the percent of such groups in the total population; for this EIS, a minority population is one in which the percent of the total population comprising of a racial or ethnic minority is 10 percentage points or more higher than the percent of such groups in the total population (DIRS 103162-CEQ 1997, all). Nevada had a minority population of 34.8 percent in 2000 (see Chapter 3, Section 3.1.13 for a discussion of population information). For this EIS, therefore, one focus of the environmental justice analysis is the potential for transportation-related activities of the Proposed Action to have disproportionately high and adverse impacts on the populations in census tracts in the region of influence (principally in Clark, Nye, and Lincoln Counties) with a minority population of 44.8 percent or higher.

Nevada had a low-income population of 10 percent in 1990. Using the approach described in the preceding paragraph for minority populations, a low-income population is one in which 20 percent or more of the persons in a census block group live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements (DIRS 152051-OMB 1999, all; DIRS 103127-Bureau of the Census 1999, pp. 114 and 116). Therefore, the second focus of the environmental justice analysis for this EIS is the potential for the Proposed Action to have disproportionately high and adverse impacts on the populations in census block groups with a low-income population of 20 percent or higher.

In response to comments, DOE has updated and refined available information to determine whether the Draft EIS overlooked any unique exposure pathways or unique resource uses that could create opportunities for disproportionately high and adverse impacts to minority and low-income populations, even though the impacts to the general population would not be high and adverse. The Department identified and analyzed several unique pathways and resources (for example, cultural and aesthetic resources, land use, air quality, and noise), but none revealed a potential for disproportionately high and adverse impacts (see Section 6.3 and Appendix J, Section J.3). DOE has updated and refined information germane to environmental justice analysis, including additional and more detailed mapping of minority populations (see Appendix J, Section J.3.1.2).

Section 6.3.4 describes the results of the analysis for the Nevada transportation scenarios.

6.3.1 IMPACTS OF THE NEVADA MOSTLY LEGAL-WEIGHT TRUCK TRANSPORTATION SCENARIO

Legal-weight truck shipments in Nevada of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site would use existing highways (see Figure 6-13) and would be a very small fraction of the total traffic [less than 600,000 kilometers (370,000 miles) per year for legal-weight truck shipments in Nevada in comparison to an estimated 1.2 billion kilometers (750 million miles) per year of commercial vehicle traffic on I-15 and U.S. Highway 95 in southern Nevada]. As a consequence, impacts to land use; hydrology; biological resources; cultural resources; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management would not be large.

Because of a U.S. Fish and Wildlife Service concern about populations of desert tortoises and Clark County concern about air quality in the Las Vegas air basin, this section addresses the potential for impacts to this threatened species and to the quality of air in the basin. This section focuses on impacts to occupational and public health and safety in Nevada. Section 6.3.4 contains a consolidated discussion of the potential for transportation activities to cause environmental justice concerns.

6.3.1.1 Impacts to Air Quality

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) for the transportation activities of the mostly legal-weight truck scenario. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of vehicle emissions (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). The review determined that during repository-related operations, when maximum emissions would occur, the transportation of employees, materials, and supplies, and the transportation of spent nuclear fuel and high-level radioactive waste would not exceed the General Conformity threshold levels for carbon monoxide. Total emissions would be 63 metric tons (69 tons) per year (69 percent of the threshold) and 0.25 metric ton (0.28 ton) per day (0.07 percent of the 2000 daily carbon-monoxide levels in the Las Vegas air basin) (DIRS 156706-Clark County 2000, Appendix A, Table 1-3).

The DIRS 155112-Berger (2000, p. 55) estimate for transportation of radioactive materials only for the legal-weight truck transport for 2010 is 0.27 metric ton (0.03 ton) per day. This estimate includes traffic congestion emissions. Although DOE believes the estimate is high, a value of 0.03 ton per day, 5 days per week, 50 weeks per year, would result in about 6.8 metric tons (7.5 tons) of carbon monoxide per year, which is less than 10 percent of the threshold.

6.3.1.2 Impacts to Biological Resources

Legal-weight truck shipments in Nevada to a Yucca Mountain Repository would involve travel over highways that cross desert tortoise habitat, but none of the routes would cross habitat that the U.S. Fish and Wildlife Service has designated as critical for the recovery of this threatened species (50 CFR 17.95). Over the course of 24 years of operations under the Proposed Action and 53,000 shipments, vehicles probably would kill individual desert tortoises. However, under this scenario legal-weight trucks would contribute only about 1 percent to the daily traffic of vehicles to and from the repository site and only about 0.15 percent of all commercial truck traffic along I-15 and U.S. 95 in southern Nevada. Thus, any desert tortoises killed by trucks transporting spent nuclear fuel or high-level radioactive waste probably would be only a small fraction of all desert tortoises killed on highways. Loss of individual desert tortoises due to legal-weight truck shipments would not be a large threat to the conservation of this species. DOE is engaged in consultation with the U.S. Fish and Wildlife Service to ensure protection of desert tortoises and other biological resources.

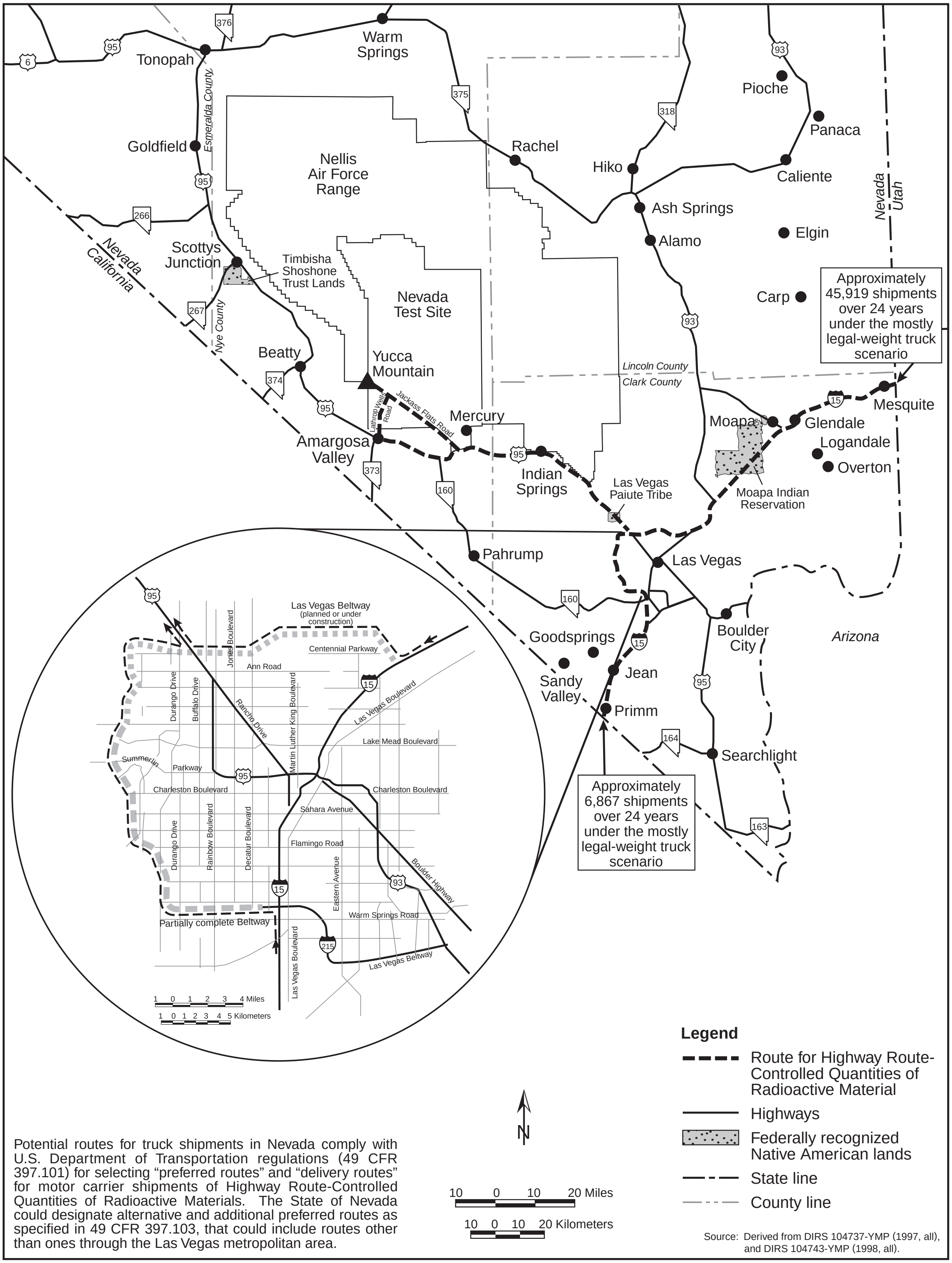

Figure 6-13. Potential Nevada routes for legal-weight trucks and estimated number of shipments.

6.3.1.3 Impacts to Occupational and Public Health and Safety

6.3.1.3.1 *Impacts from Incident-Free Transportation*

This section addresses radiological impacts to populations and maximally exposed individuals in Nevada from the incident-free transportation of spent nuclear fuel and high-level radioactive waste for the mostly legal-weight truck scenario. It includes potential impacts from exposure to vehicle emissions in Nevada.

Incident-Free Radiological Impacts to Populations. Table 6-18 lists the incident-free population dose and radiological impacts for the Nevada mostly legal-weight truck scenario. The impacts include those from the shipment of naval spent nuclear fuel by rail in Nevada to an intermodal transfer station, heavy-haul transfer activities, and subsequent heavy-haul truck transportation to the proposed repository. The analysis included the radiological impacts of intermodal transfer operations for naval spent nuclear fuel shipments. Occupational impacts would include estimated radiological exposures to security escorts for legal-weight truck, rail, and heavy-haul truck shipments. The estimated radiological impacts would be 0.75 latent cancer fatality for workers and 0.18 latent cancer fatality for members of the public over the 24 years of operation.

Table 6-18. Population doses and radiological health impacts from incident-free transportation for Nevada mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	1,900	18	1,900
Estimated LCFs[d]	0.75	0.01	0.75
Public			
Collective dose (person-rem)	340	10	350
Estimated LCFs	0.17	0.005	0.18

a. Impacts are totals for shipments over 24 years.
b. Includes impacts at intermodal transfer stations.
c. Totals might differ from sums of values due to rounding.
d. LCF = latent cancer fatality.

DOE based estimated impacts of legal-weight truck shipments in Nevada on routes identified for analysis in accordance with requirements in U.S. Department of Transportation regulations (49 CFR 397.101). As required by those regulations, and because the Las Vegas Beltway will be part of the Interstate Highway System, DOE assumed its use to avoid travel through the heavily traveled center of Las Vegas. In addition, DOE analyzed the potential impacts of using other routes that the State of Nevada has studied and of routing shipments through the Interstate 15-U.S. 95 interchange (the *"Spaghetti Bowl"*). Appendix J, Section J.3.1.3 discusses the results of these analyses, which range from 83 to 490 person-rem (0.04 to 0.25 latent cancer fatality in the affected population) for Nevada populations.

Incident-Free Radiological Impacts to Maximally Exposed Individuals. Table 6-19 lists estimates of dose and radiological impacts for maximally exposed individuals for the Nevada legal-weight truck scenario from 24 years of shipment activity. The analysis used the assumptions presented in Section 6.2.1 and Appendix J.

The analysis assumed the annual dose to state inspectors who conducted frequent inspections of shipments of spent nuclear fuel and high-level radioactive waste would be limited to 2 rem.

The analysis estimated that a maximally exposed individual at a service station would receive 2.4 person-rem over 24 years under the legal-weight truck scenario. This estimate conservatively assumed the person would be exposed to 450 truck shipments each year for 24 years. For perspective, under the mostly legal-weight truck scenario, which assumes an average of 2,200 legal-weight truck shipments per

Table 6-19. Estimated doses and radiological health impacts to maximally exposed individuals during incident-free transportation for Nevada mostly legal-weight truck scenario.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member	48[c]	0.02
Inspector	48[c]	0.02
Railyard crew member	0.13	0.00005
Public		
Resident along route[d]	0.02	0.00001
Person in traffic jam[e]	0.016	0.000008
Person at service station[f]	2.4	0.0012
Resident near rail stop	0.009	0.000005

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Impacts are totals over 24 years.
c. Based on 2-rem-per-year dose limit (DIRS 156764-DOE 1999, Article 211).
d. This represents a Nevada resident approximately 11 meters (36 feet) from the highway. See Appendix J, Section J.1.3.2.2.
e. Person in a traffic is assumed to be exposed one time only.
f. Assumes the person works at the service station for all 24 years of repository operations. Mitigation would be required to reduce doses to members of the public to less than 100 millirem per year.

year, about 450 truck shipments would pass through the Mercury, Nevada, gate to the Nevada Test Site in 1,800 hours. A worker at a truck stop along the route to Mercury would work about 1,800 hours per year. Thus, if every shipment stopped at that truck stop, the maximum number of shipments the worker would be exposed to in a year would be 450. Appendix J, Section J.1.3.2.2, describes assumptions for estimating doses to maximally exposed individuals along routes in Nevada.

Impacts from Vehicle Emissions. There is potential for human health impacts to people in Nevada who would be exposed to pollutants emitted from vehicles transporting spent nuclear fuel and high-level radioactive waste, including escort vehicles. Table 6-20 lists the estimated number of vehicle emission-related fatalities from legal-weight trucks, a small number of heavy-haul trucks carrying naval spent nuclear fuel, escort vehicles, and rail locomotives under the mostly legal-weight truck scenario. Trucks would be the major contributors. Less than 1 (0.093) vehicle emission-related fatality would be likely.

Table 6-20. Population health impacts from vehicle emissions during incident-free transportation for Nevada mostly legal-weight truck scenario.[a]

Category	Legal-weight truck shipments	Rail shipments of naval spent nuclear fuel[b]	Total
Vehicle emission-related fatalities	0.086	0.0069	0.093

a. Impacts are totals for shipments over 24 years.
b. Includes heavy-haul truck shipments in Nevada.

6.3.1.3.2 *Impacts from Accidents – Nevada Legal-Weight Truck Scenario*

This section discusses radiological impacts to populations and maximally exposed individuals in Nevada and the potential number of traffic accident fatalities from accidents during the transportation of spent nuclear fuel and high-level radioactive waste for the mostly legal-weight truck scenario. The analysis of accident impacts under this scenario includes impacts from accidents that would occur during the transportation of naval spent nuclear fuel by rail in Nevada to an intermodal transfer station and by heavy-haul truck to the repository. Section 6.3.3 discusses impacts to workers from industrial hazards during the operation of an intermodal transfer station for shipments of naval spent nuclear fuel.

Radiological Impacts from Accidents. The calculated collective radiological dose risk of accidents would be approximately 0.053 person-rem for the population in Nevada within 80 kilometers (50 miles) along the routes under the mostly legal-weight truck transportation scenario. This calculated dose risk would be the total for 24 years of shipment operations. The radiological dose risk of accidents is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. A radiological dose risk of 0.05 person-rem would result in much less than 1 (0.000026) latent cancer fatality in the exposed population. The radiological risk from accidents would include impacts from approximately 53,000 legal-weight truck shipments and 300 naval spent nuclear fuel rail shipments. The accident risk for legal-weight truck shipments would account for essentially all of the population dose and radiological impacts. Because DOE would not build a branch rail line to the repository under this scenario, the accident risk for rail shipments of naval spent nuclear fuel includes risks from accidents that could occur during intermodal transfers from railcars to heavy-haul trucks and during heavy-haul transportation in Nevada. Section 6.3.3 provides additional information on heavy-haul truck implementing alternatives for transporting rail casks in Nevada.

Consequences of Maximum Reasonably Foreseeable Accident Scenarios. The analysis evaluated the impacts of a maximum reasonably foreseeable accident scenario presented in Section 6.2.4.2.

Impacts from Traffic Accidents. In Nevada, less than 1 (0.49) fatality from traffic accidents would be likely during the course of transporting spent nuclear fuel and high-level radioactive waste under the mostly legal-weight truck transportation scenario. This estimate includes traffic fatalities involving escort vehicles.

MAXIMUM REASONABLY FORESEEABLE ACCIDENT SCENARIOS IN NEVADA

Maximum reasonably foreseeable accident scenarios analyzed for transportation in Nevada were the same as maximum reasonably foreseeable accident scenarios analyzed in Section 6.2.4.2 for national transportation. That is, the EIS analysis assumed that an accident determined to be reasonably foreseeable for national transportation could occur in Nevada. Because the distances traveled in Nevada would be much less than the total national travel to deliver spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, the likelihoods of these accident scenarios occurring in the State would be less than those for the rest of the Nation. The likelihoods of two of these accident scenarios occurring in national travel are reported in Section 6.2.4.2.

6.3.2 IMPACTS OF NEVADA RAIL TRANSPORTATION IMPLEMENTING ALTERNATIVES

This section describes the analysis of human health and safety and environmental impacts for five rail transportation implementing alternatives, each of which would use a newly constructed branch rail line in Nevada to transport spent nuclear fuel and high-level radioactive waste to the repository. The branch line would transport railcars carrying large shipping casks from a mainline railroad to the repository (loaded) and back (empty). DOE has identified five 400-meter (0.25-mile)-wide corridors of land—Caliente, Carlin, Caliente-Chalk Mountain, Jean, and Valley Modified—for the possible construction and operation of the branch line (Figure 6-14). Chapter 2, Section 2.1.3.3.2 describes the corridors. Chapter 3, Section 3.2.2.1, discusses their affected environments.

Appendix J, Section J.3.1.2, contains additional information on the characteristics of possible variations of each corridor. Figure 6-14 shows these variations. Section 6.3.2.1 discusses impacts that would be common among the five possible corridors, and Section 6.3.2.2 discusses impacts that would be unique for each corridor.

DOE identified the five rail corridors through a process of screening the potential rail corridors it had studied in past years.

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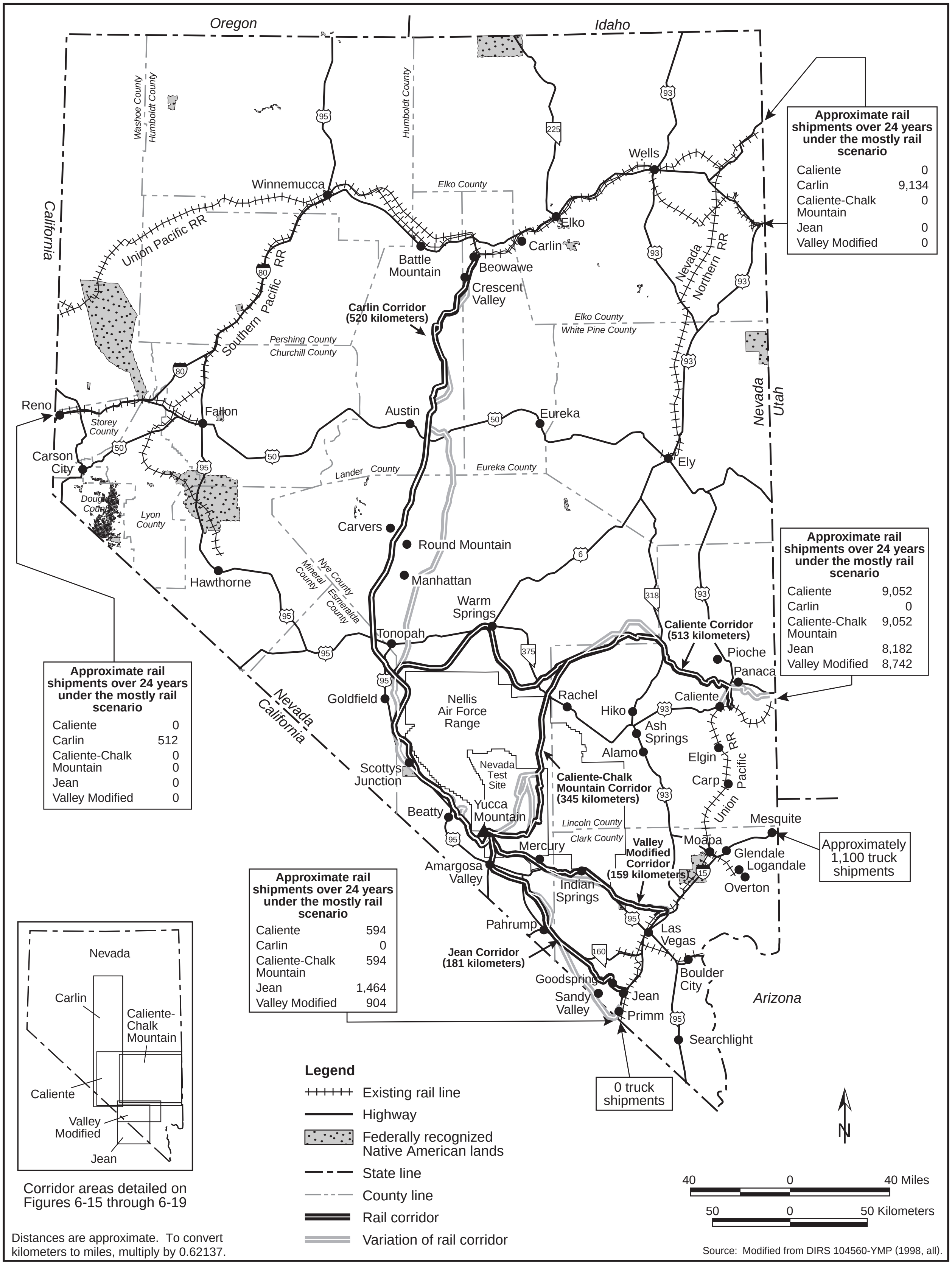


Figure 6-14. Potential Nevada rail routes to Yucca Mountain and estimated number of shipments for each route.

- The *Feasibility Study for Transportation Facilities to Nevada Test Site* study (DIRS 104777-Holmes & Narver 1962, all) determined the technical and economic feasibility of constructing and operating a railroad from Las Vegas to Mercury.

- The *Preliminary Rail Access Study* (DIRS 104792-YMP 1990, all) identified 13 and evaluated 10 rail corridor options. This study recommended the Carlin, Caliente, and Jean Corridors for detailed evaluation.

- *The Nevada Railroad System: Physical, Operational, and Accident Characteristics* (DIRS 104735-YMP 1991, all) described the operational and physical characteristics of the current Nevada railroad system.

- The *High Speed Surface Transportation Between Las Vegas and the Nevada Test Site (NTS)* report (DIRS 104786-Cook 1994, all) explored the rationale for a potential high-speed rail corridor between Las Vegas and the Nevada Test Site to accommodate personnel.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 1* (DIRS 104795-CRWMS M&O 1995, all), reevaluated 13 previously identified rail routes and evaluated a new route called the Valley Modified route. This study recommended four rail corridors for detailed evaluation—Caliente, Carlin, Jean, and Valley Modified corridors.

- The *Nevada Potential Repository Preliminary Transportation Strategy, Study 2* (DIRS 101214-CRWMS M&O 1996, all), further refined the analyses of potential rail corridors in Study 1.

Public comments submitted to DOE during hearings on the scope of this EIS resulted in the addition of a fifth potential rail corridor—Caliente/Chalk Mountain.

The analysis of impacts for the five Nevada rail transportation implementing alternatives assumed the mostly rail transportation scenario. Therefore, the analysis included the impacts of legal-weight truck transportation from six commercial sites that would not have the capability while operational to handle or load a large rail cask. About 1,079 legal-weight truck shipments over 24 years would enter Nevada and travel to the repository. These shipments would use the same transport routes and carry about the same amounts of spent nuclear fuel per shipment as those described for the mostly legal-weight truck scenario (Section 6.3.1).

The analysis evaluated impacts to land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.1 Impacts Common to Nevada Branch Rail Line Implementing Alternatives

The estimated life-cycle cost of constructing and operating a branch rail line in Nevada would range from $283 million to $880 million (2001 dollars), depending on the corridor and variation. This section discusses impacts for the analysis areas listed above that would be common to all five branch rail line implementing alternatives. DOE evaluated these impacts as described in Section 6.3. The construction of the branch rail line would last between 40 and 46 months, depending on the rail corridor. Shipping operations in the rail corridor would begin at a mainline siding where railcars carrying casks of spent nuclear fuel and high-level radioactive waste would switch from the mainline to the branch line for transport to the repository, and railcars carrying empty casks from the repository would switch to the mainline for transport back to the commercial and DOE sites. These shipments would continue for 24 years. Section 6.3.2.2 discusses impacts specific to each rail implementing alternative.

6.3.2.1.1 *Common Rail Land-Use and Ownership Impacts*

In identifying the land potentially affected by a rail corridor, the analysis assumed a corridor width of 400 meters (1,300 feet, or about 0.25 mile). The purpose of the 400-meter width was to provide sufficient space for final alignment to route the rail line around sensitive land features or engineering obstacles. Actual construction and operation in the corridor would mostly require less than about 60 meters (200 feet) of the 400-meter width. Thus, at most, about 15 percent of the land in the corridor would be disturbed by construction. The analysis also assumed that as much as 3.6 square kilometers (890 acres) of land outside of the main disturbed area within the corridor would be disturbed during the construction of a branch rail line for construction roads and camps and other construction-related activities.

Each rail corridor has possible variations providing different land ownerships and projected disturbances, as described in Appendix J, Section J.3.1.2. These possible variations would make little difference in land-use impacts, which could be more or less than those described below.

The analysis indicates no conflicts with commercial use and no identified conflicts with scientific studies for any of the proposed corridors. At present, the public land in each corridor, with the exception of portions of the Caliente-Chalk Mountain Corridor, is open to mining and recreational use, as discussed in Chapter 3, Section 3.2.2.1.1.

The construction and operation of a branch rail line in any of the rail corridors would directly and indirectly affect private property. The Valley Modified Corridor would have the smallest range of private land affected, from 7.3 to 0.2 square kilometer (45 acres). The Carlin Corridor would have the largest, from 7.3 to 15 square kilometers (1,800 to 3,700 acres). Most of the private property in the Carlin Corridor is in the vicinity of Beowawe and Crescent Valley. The ownership of each parcel of affected private land would require that DOE negotiate use arrangements with owners. The division of private property parcels could affect the current and future use of the property. Each corridor contains lands associated with the Nevada Test Site and managed by DOE. The amount of land in each corridor varies from 5 square kilometers (1,200 acres) for the Carlin and Caliente Corridors to 38 square kilometers (9,400 acres) for the Caliente-Chalk Mountain Corridor. With the exception of the Caliente-Chalk Mountain Corridor, the corridors cross Nevada Test Site lands only at entry points to the repository site close to the perimeter of the property and would be unlikely to result in a change of current land use. The Caliente-Chalk Mountain Corridor would enter the northeast portion of the Test Site and pass generally through the center of the site. Although this corridor would not result in a change of ownership, it would alter the current use of the land in the vicinity of the rail corridor.

Each rail corridor, with the exception of the Jean Corridor, would cross a portion of the Nellis Air Force Range (also known as the Nevada Test and Training Range) under the management of the U.S. Air Force. Lands along the corridors managed by the Air Force range from none for the Jean Corridor to 22 square kilometers (5,400 acres) for the Caliente-Chalk Mountain Corridor. The Caliente-Chalk Mountain Corridor would enter Nellis Air Force Range lands along the northern boundary and cross approximately 52 kilometers (32 miles) of land used for Department of Defense training operations.

The U.S. Air Force has identified national security issues in relation to a Caliente-Chalk Mountain Corridor, citing interference with Nellis Air Force Range testing and training activities (DIRS 104887-Henderson 1997, all). In response to Air Force concerns, DOE regards this route as a “nonpreferred alternative.”

As of July 2001, the Nevada Public Utility Commission’s website listed 20 electric power generating facilities scheduled for construction in Nevada by 2004. Five of the 20 plants have received permits to proceed. Two of these are located in Storey County and Pershing County. Three are in Clark County—one in North Las Vegas and two for the same company in an industrial park at Apex. None is anticipated to impact land use for the repository or the transportation routes. The remaining 15 sites are anticipated to begin construction through 2002. The rights-of-way associated with the new plants are likely to cross Bureau of Land Management land. Of the 20 plants proposed, 13 are scheduled for construction in Clark County. These are on private, public, and reservation lands. None of the 20 proposed power plants would be within 50 miles (80 kilometers) of the proposed repository at Yucca Mountain. In addition, none of the proposed plant locations would conflict with any of the proposed transportation route options. The transmission lines and natural gas utility rights-of-way for the proposed locations could cross potential transportation routes. Current documentation is not sufficient to determine the locations for the proposed transmission line and natural gas rights-of-way. Conflicts due to proposed power plant rights-of-way would predominantly be associated with the proposed rail corridors and would be similar to existing rights-of-way discussed later in this section.

Each corridor has areas the public uses and areas available for sale and transfer. Each corridor crosses some roads used to access recreation areas on State of Nevada and Federal lands that are outside the corridors. As a consequence, the proposed branch rail line could result in limited access to areas currently in use by the public. Similarly, because of the corridor interface with grazing lands and wildlife areas, a rail line could create a barrier to livestock movement. Impacts to wildlife are discussed later in this section. Each corridor crosses road, highway, or utility rights-of-way. The passage of a branch rail line through these areas could result in land-use conflicts that, in turn, could result in the transfer of lands in the rights-of-way to DOE or a renegotiation of rights-of-way.

Construction. DOE expects the potential impacts of construction to be greater than those during the operation of a rail corridor. If the repository was approved and a rail corridor was selected, the following impacts from the construction of a branch rail line could occur:

- Difficulty for cattle to access water if the corridor divided Bureau of Land Management grazing allotments. Disruption of ranch operations and livestock rotations. Livestock deaths along roads used during construction. Disruptions to use of access roads to grazing allotments which typically consist of two-track roads and crisscross many of the corridors.

- Effects to private property divided by a branch rail line if alternative access was not available or provided. Although DOE would mitigate construction activities through stringent construction practices, those practices could affect property use, especially if the property was inhabited.

- Effects to mining activities such as mine operations or exploration if access roads were temporarily blocked or altered. Divided mining claims, making development of a claim less profitable if access became a problem.

- Effects on access to recreational areas. Division of some Bureau of Land Management lands currently used for recreation, which could temporarily isolate sections of land from the general public. Less ease of access in areas where Federal and State recreation areas can be accessed by roads (including two-track roads) from Bureau lands. Alteration of the recreational experience for some users; for example, construction of a rail corridor close to Bureau lands set aside for primitive and semiprimitive recreational use would alter those experiences.

- Effects on rights-of-way. Construction through these areas would require an evaluation of the impact to the road or utility or use of the right-of-way. Alteration of the construction of current roads or utility lines. Alteration of above-ground utility lines to pass beneath the branch rail line through an underpass to enable continued access to the utilities for maintenance. Movement of overhead transmission towers and poles to accommodate the branch rail line. Use of bridges or underpasses across high-volume roads to preclude at-grade crossings. Use of fencing where increased public contact could occur.

DOE would consult with the Bureau of Land Management, U.S. Air Force, other affected agencies, and other DOE program operations on the Nevada Test Site to help ensure that the final alignment of a branch rail line avoided or mitigated potential land-use conflicts.

Operations. DOE expects the operation of a rail line to cause smaller impacts than would construction. If the repository was approved and a rail corridor was selected, the following impacts of the operation of a branch rail line could occur:

- Division of some grazing lands. The Bureau of Land Management has stated that dividing grazing lands would result in a small loss of animal-unit months in large allotments, but would probably not affect ranch operations as long as there was available access across the corridor. (An *animal-unit month* represents enough dry forage for one mature cow for one month.) The loss of animal-unit months could affect the permittee's operation. In addition, the Bureau indicated that, if a branch rail line divided an allotment into separate pastures, an opportunity to rotate pasture use and thereby enable new grazing management options could be beneficial to livestock and vegetation. The Bureau acknowledges that fencing could be required along corridors where there are grazing allotments and that livestock could be isolated from water. Under these circumstances, water would have to be hauled to livestock or supplied in some other manner. In relation to branch rail line operations, train and track inspection and maintenance activities would be confined to areas disturbed by construction activities, so no additional disturbances would occur.

- No additional impacts to land use as long as there was property accessibility.

- No effects on mining activities over the long term. Effects on mining exploration if access to leases was blocked or restricted, but current mining operations probably would remain accessible.

- Effects to access to recreational areas. Division of Bureau of Land Management lands currently used for recreation and for access to Federal and State lands, which could limit access to portions of those lands. Alteration of the recreational experience for some users; for example, operation of a rail corridor close to Bureau lands set aside for primitive and semiprimitive recreational use could alter those recreational experiences.

6.3.2.1.2 *Common Rail Air Quality Impacts*

Construction. The construction of a branch rail line would comply with all applicable air quality regulations and associated requirements in the construction permits. Construction activities would increase pollutant concentrations in the areas near the rail corridor or any of the variations described in subsequent sections. Fuel use by construction equipment would emit carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter with diameters of 10 micrometers or less (PM_{10}) and 2.5 micrometers or less ($PM_{2.5}$). Construction activities would also emit PM_{10} in the form of fugitive dust from excavation and truck traffic. The emissions would be temporary and would cover a very large area as construction moved along the length of the corridor.

No air quality impacts would be unique to the branch rail line implementing alternatives with the exception of the Valley Modified Corridor, as described in Section 6.3.2.2.5.

Operations. Fuel use by diesel train engines would emit carbon monoxide, nitrogen dioxide, PM_{10}, and $PM_{2.5}$. Based on the Federal standards for locomotives (40 CFR 92.005), there are no emission standards for sulfur dioxide.

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) for the transportation activities of the Nevada rail implementing alternatives. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of vehicle emissions (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). The review determined that during the construction phase carbon monoxide emissions from the transportation of employees, materials, and supplies and from engine exhaust of construction vehicles working on the Valley Modified route could exceed the Clean Air Act General Conformity threshold level (about 110 to 160 percent of the threshold). These emission estimates represent about 0.1 to 0.2 percent of the 2000 daily carbon monoxide levels in the Las Vegas air basin. More detailed planning probably would result in emissions below the threshold. Emissions during the construction of all other routes and during repository operations would not exceed the carbon monoxide General Conformity threshold level in the nonattainment area.

The Las Vegas air basin is also in nonattainment status for PM_{10}, which is largely a result of dust from construction activities (DIRS 155557-Clark County 2001, Tables 3-8 and 5-3). The conformity review determined that PM_{10} emissions from the fugitive dust generated by Valley Modified route construction could exceed the General Conformity threshold level for PM_{10} (see Section 6.3.2.2.5.2). Additional dust control measures and construction planning in the nonattainment area could reduce the emissions to levels below the threshold. Emissions during the construction of all other routes and during the operation of any of those routes would not exceed the PM_{10} General Conformity threshold levels in the nonattainment area.

No air quality impacts would be unique to the branch rail line implementing alternatives with the exception of the Valley Modified Corridor, as described in Section 6.3.2.2.5.

6.3.2.1.3 *Common Rail Hydrology Impacts*

This section describes impacts to surface water and groundwater.

Surface Water

Construction. Construction-related impacts could involve the possible release and spread of contaminants by precipitation or intermittent runoff events or, for corridors near surface water, possible release to the surface water, the alteration of natural drainage patterns or runoff rates that could affect downgradient resources, and the need for dredging or filling of perennial or ephemeral streams.

Construction-related materials that could cause contamination would consist of petroleum products (fuels and lubricants) and coolants (antifreeze) necessary to support equipment operations. In addition, remote work camps would include some bulk storage of these materials, and supply trucks would routinely bring new materials and remove used materials (lubricants and coolants) from the construction sites. These activities would present some potential for spills and releases. Compliance with regulatory requirements on reporting and remediating spills and properly disposing of or recycling used materials would result in a low probability of spills. If a spill occurred, the potential for contamination to enter flowing surface water would present the greatest risk of a large migration of a contaminant before remediation took place. If there was no routinely flowing surface water (most areas along the corridors), released material would not travel far or affect critical resources before remediation occurred. During construction activities, water spraying would control dust and achieve soil compaction criteria, but water would not be used in quantities large enough to support surface-water flow and possible contaminant transport for any distance.

During construction, a contractor would move large amounts of soil and rock to develop the track platform (subgrade) and the access road. These construction activities could block storm drainage channels temporarily. However, the contractor would use standard engineering design and best management practices to place culverts, as appropriate, to move runoff water from one side of the track or road to the other. These culverts or other means of runoff control would be put in place early in the construction effort, because standing water in the work area would generally hinder progress.

Depending on site-specific conditions, construction could include regrading such that a number of minor drainage channels would collect in a single culvert, resulting in water flowing from a single location on the downstream side rather than across a broader area. This would cause some localized changes in drainage patterns but probably would occur only in areas where natural drainage channels are small.

All of the rail corridors would cross 100-year flood zones as identified on Flood Insurance Rate Maps published by the Federal Emergency Management Agency. None of the corridors has complete coverage (the percentage of the rail corridor included on the flood zone maps) on these maps due to large unstudied areas such as the Nellis Air Force Range and the Nevada Test Site, and areas with very limited coverage such as Lincoln County. For example, coverage by these flood maps ranges from about 10 percent for the Caliente-Chalk Mountain Corridor to about 90 percent for the Jean Corridor. However, the available information does provide an idea of corridor-specific flood zones, as summarized in the individual corridor discussions in Sections 6.3.2.2.1 to 6.3.2.2.5. In general, construction-related impacts associated with these flood zones would be very similar to those that could occur in any other identified drainage areas (that is, the alteration of natural drainage patterns and possible changes in erosion and sedimentation rates or locations). Construction in washes or other flood-prone areas probably would reduce the area through which floodwaters naturally flow. This could result in water building up, or ponding, on the upstream side of crossings during flood events, and then slowly draining through the culverts or bridges. Sedimentation would be likely on the upstream side of structures in such events and, accordingly, water going through the structure could be more prone to cause erosion once on the downstream side. Maintenance of a branch rail line would require periodic inspections of flood-prone areas (particularly after flood events) to verify the condition of the track and drainage structures. When necessary, sediment accumulating in these areas would be removed and disposed of appropriately. Similarly, eroded areas encroaching on the track bed would be repaired.

These alterations to natural drainage, sedimentation, and erosion would be unlikely to increase future flood damage, increase the impact of floods on human health and safety, or cause significant harm to the natural and beneficial values of the floodplains. Flood zone impacts would be minor primarily because of the relatively limited size of the disturbance that would be necessary to construct a branch rail line, and because the rail line design would accommodate a 100-year flood. In addition, the candidate rail corridors are in a region where flash flooding events are the primary concern. Though such flooding can be very violent and hazardous, it is generally focused in its extent and duration, limiting the potential for extensive impacts associated with the rail line. If DOE selected a rail corridor, it would initiate additional engineering and environmental studies and would perform additional National Environmental Policy Act reviews as a basis for final alignment selection and construction. DOE would then prepare a more detailed floodplain/wetlands assessment of the selected alternative.

Operations. The use of a completed branch rail line would have little impact on surface waters beyond the permanent drainage alterations from construction. The road and rail beds probably would have runoff rates different from those of the natural terrain but, given the relatively small size of the potentially affected areas in a single drainage system, there would be little impact on overall runoff quantities.

There would be no surface-water impacts unique to any of the branch rail line implementing alternatives with the exception of their relative proximity to surface-water resources.

Appendix L contains a floodplain/wetlands assessment that examines the effects of branch rail line construction, operation, and maintenance on the following floodplains in the vicinity of Yucca Mountain: Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash (see Section L.4.1). There are no delineated wetlands at Yucca Mountain. This section on common impacts and the following section on corridor-specific impacts address, in general terms, the flood zones along the rail corridors outside the immediate vicinity of Yucca Mountain. Appendix L, Section L.3.2, contains additional information on these portions of the corridors.

Groundwater

Construction. Potential groundwater impacts from rail line construction could include changes to infiltration rates, new sources of contamination that could migrate to groundwater, and depletion of groundwater resources resulting from increased demand. However, the potential for impacts would be spread over a large geographic area, so the probability would be low for a resource in a single area to receive adverse impacts. The above discussion of impacts to surface water identifies potential contaminants that branch rail line construction could release. These contaminants would be the same for groundwater.

Construction activities would disturb and loosen the ground, which could produce greater infiltration rates. However, this situation would be short-lived as the access road and railbed materials became compacted and less porous. In either case, localized changes in infiltration probably would cause no noticeable change in the amount of recharge in the area.

The analysis assumed that a number of wells would be required to support construction and that they would be installed along the rail corridor. It also assumed a 1-year period for construction activities in the vicinity of each well. Water withdrawal from these wells would not contribute to the depletion of a particular groundwater basin for two reasons: (1) the demand would be relatively short-term because it would stop when construction was complete, and (2) annual demands would be limited to a fraction of the perennial yields of the aquifers that would supply the water (see Chapter 3, Section 3.1.4). In addition, the Nevada State Engineer would approve water production from any well installed to support rail corridor construction. To grant approval, the State Engineer would have to determine that the short-term demand would not cause adverse impacts for other uses and users of the groundwater resource.

For the case in which water was obtained from a source other than a newly installed well and brought to the construction site by truck, water would be obtained from appropriated sources. That is, the water would be from allocations that the Nevada State Engineer had previously determined did not adversely affect groundwater resources.

Impacts on groundwater would differ among the implementing alternatives. These impacts, which Section 6.3.2.2 describes for the implementing alternatives, would include the projected water needs to support the construction of each candidate rail corridor and the estimated number of wells DOE would install along each corridor to meet that need.

Operations. The use of a completed railway corridor would have little impact on groundwater resources. There would be no continued need for water along the corridor, and possible changes to recharge, if any, would be the same as those at the completion of construction.

6.3.2.1.4 *Common Rail Biological Resources and Soils Impacts*

Construction. Construction activities would generally disturb no more than about 15 percent of the land inside a 400-meter (0.25-mile)-wide corridor. Vegetation would be cleared in an area generally less than 60 meters (200 feet) wide in the corridor to enable the construction of a branch rail line and a parallel access road. Vegetation would also be cleared from borrow areas and covered in disposal areas for excavated materials. Land for construction camps and in small areas where wells would be drilled would also be cleared of vegetation. Clearing vegetation and disturbing the soil would create habitat for colonization by exotic plant species present along a corridor. This could result in an increase in abundance of exotic species along the corridor, which could result in suppression of native species and increased fuel loads for fire. Reclamation of disturbed areas would enhance the recovery of native vegetation and reduce colonization by exotic species.

Impacts to biological resources from the construction of a branch rail line would occur due to a loss of habitat for some terrestrial species. Individuals of some species would be displaced or killed by construction activities. After the selection of a rail corridor, DOE would perform preconstruction surveys of potentially disturbed areas to identify and locate special status species that would need to be protected during construction.

Construction could affect the following biological resources:

- *Game and Game Habitat and Wild Horses and Burros.* Each candidate rail corridor or its variations would cross or be near [within 5 kilometers (3 miles)] several areas the Bureau of Land Management and the Nevada Division of Wildlife have designated as game habitat or wild horse and burro management areas (DIRS 104593-CRWMS M&O 1999, pp. 3-23 to 3-32). Construction activities in these areas would result in a loss of some habitat. Each rail corridor has the potential to disrupt movement patterns of game animals and wild horses and burros. The design of fences, if built along a rail corridor, would accommodate the movement of these animals. Large animals including game species (elk, bighorn sheep, mule deer, etc.), wild horses, and burros probably would avoid contact with humans at construction locations and would temporarily move to other areas during construction. Larger game animals occupy large home ranges and could easily traverse the distance between their designated habitat and a proposed corridor. Construction activities probably would disturb individuals or groups of animals and they would avoid the areas where construction was occurring. Fencing of the rail line could disrupt movements of horses, burros, and game animals, but the branch rail line would be designed to accommodate animal movement, to the extent possible, with such features as underpasses to enable large animals to cross from one side to the other. In the absence of fencing, movements of large animals would not be disrupted by the long-term presence of a rail line, but the possibility of trains colliding with game animals would be greater.

- *Special Status Species.* The construction of a branch rail line in any of the five rail corridors or their variations would involve the loss of varying amounts [3 to 11 square kilometers (740 to 2,700 acres)] of desert tortoise habitat. None of the corridors cross areas designated by the Fish and Wildlife Service as critical desert tortoise habitat (50 CFR 17.95). The abundance of tortoises varies from very low to medium along the proposed corridors (DIRS 101840-Karl 1980, pp. 75 to 87; DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411), but some desert tortoise deaths could occur during land-clearing operations. Numerous special status species occur along each of the proposed branch rail lines. Construction of a branch rail line could lead to habitat loss and fragmentation for the special status species, as well as to mortality of individuals.

- *Wetlands and Riparian Areas.* Each corridor could affect wetlands, springs, and riparian areas (DIRS 104593-CRWMS M&O 1999, pp. 3-23 to 3-32). These areas are generally important for biological resources and typically have high biodiversity. Potential impacts to these areas include destruction, alteration, or fragmentation of habitat; increased siltation in streams during construction; changes in stream flow; and loss of biodiversity.

- *Prime Farmland.* DOE identified no prime farmland for any corridor or route.

Section 6.3.2.2 describes the impacts to biological resources that would be unique for each corridor.

All of the candidate rail corridors and their variations would cross perennial or ephemeral streams that could be classified as jurisdictional waters of the United States. Section 404 of the Clean Water Act regulates discharges of dredged or fill material into such waters. After the selection of a rail corridor, DOE would identify any jurisdictional waters of the United States that the construction of a rail line would affect; develop a plan to avoid when possible, and otherwise minimize, impacts to those waters;

and, as applicable, obtain an individual or regional permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material. By implementing the plan and complying with other permit requirements, DOE would ensure that impacts to waters of the United States would be small.

The general design criteria for a branch rail line would include a requirement that a 100-year flood would not inundate the rails at channels fed by sizable drainage areas. During the operation and monitoring phase of the repository, conditions more intense than those that would generate a 100-year storm could occur in the area. Such conditions, depending on their intensity, could wash out access roads and possibly even the rail line. Although DOE would have to repair these structures, there is no reason to believe that such an occurrence would unduly affect area resources. If necessary, a permit would be obtained from the U.S. Army Corps of Engineers for discharge of dredge and fill material to repair the rail line. There would be no contamination that floodwaters could spread and, with the exception of areas of steep terrain, debris would not travel far. The operation of a branch rail line would stop during conditions that could lead to the flooding of track areas and would not resume until DOE had made necessary repairs.

Soil impacts from branch rail line construction would be primarily the direct impacts of land disturbance in the selected corridor. The amount of land disturbance, both inside and outside the corridor, would vary by corridor. The disturbed areas probably would be subject to an increase in erosion potential during construction. DOE would use dust suppression measures to reduce this potential. As construction proceeded, the railbed would be covered with ballast rock, which would virtually halt erosion from that area, and the access roads would be compacted, and gravelled, which would reduce erosion. As construction ended, disturbed areas (other than the railbed and access roads) would slowly recover. Other permanent erosion control systems would be installed as appropriate. Introduction of contaminants into the soil is also a potential concern. Proper control of hazardous materials during construction and prompt response to spills or releases would, however, reduce this concern. Impacts to soils would be limited to these areas disturbed and would be transitory and small.

Operations. Impacts to biological resources from shipments of spent nuclear fuel and high-level radioactive waste to the proposed repository along any of the five rail corridors, including their variations, would include periodic disturbances of wildlife from trains going by and from personnel servicing the corridor. Trains probably would kill individuals of some species.

Rail operations would not lead to additional habitat losses, although maintenance activities would prevent habitat recovery in the narrow band occupied by the branch rail line and access road. In addition, there could be loss of habitat due to inadvertent fires along the right-of-way from rolling equipment operations and maintenance activities. Although trains probably would kill individuals of some species, losses would be unlikely to affect regional populations of any species because all species are widespread geographically and trains would only use the corridor once or twice per day. Fewer individuals of large species would be likely to be killed during operations if the corridor was fenced, but fencing could restrict animal movement and disrupt migration patterns. Furthermore, fences would require continual surveillance to prevent individual animals or herds from becoming trapped. Nevertheless, the demographics of small herds could be adversely affected if individuals important to the viability of the herd were struck by a train. Fencing of the branch rail line and other features, such as tunnels (Jean Corridor), could lead to losses of individual animals or groups of animals. Individual animals could become caught inside fenced sections of the railroad and fail to find escape from oncoming trains. Game animals, horses, or burros could seek shelter in a tunnel and fail to escape if a train passed through.

Passing trains could disrupt wildlife, including game animals, horses, and burros, but such effects would be transitory. Noise from a train probably would disturb animals close to the track throughout operations, but this disturbance would diminish with distance from the track and over time as animals acclimated to daily disturbances from passing trains. The frequency of trains using the corridor (estimated to be 10 per week, 5 in each direction) indicates that disturbance of animals near the rail line would probably be minimal. Noise from the trains could cause animals to move away from the tracks and, possibly, cause changes in migratory patterns.

Trains, and the presence of the branch rail line, could lead to the death of individual desert tortoises. DOE would consult with the Fish and Wildlife Service under Section 7 of the Endangered Species Act on means of mitigating the potential for losses, and would implement all terms and conditions required by the Fish and Wildlife Service.

No additional habitat loss would occur during operations, although the loss of habitat could become permanent if a long-term use for the rail line became viable after completion of the repository project and operations continued.

Impacts to soils from operation of the branch rail line would be small because train movement would not disturb soils and maintenance of the railbed and rails would involve minimal disturbance beyond that which had occurred during the construction of the rail line.

6.3.2.1.5 *Common Rail Cultural Resources Impacts*

Construction. Chapter 3, Section 3.2.2.1.5 lists the archaeological information currently available in each corridor that branch rail line construction could affect, including tables that list linear historic properties (for example, the Pony Express Trail) and sites listed on State of Nevada and national historic registers, respectively. DIRS 155826-Nickens and Hartwell (2001, all) contains more information about known and potential cultural resources along the candidate corridors and their variations. Direct impacts to these cultural resources (such as disturbing the sites or crushing artifacts) could occur from a variety of construction-related activities, including building the rail line and the right-of-way. In addition, rail line construction activities would include borrow areas, areas for the disposal of excavated material, construction camps, and access roads that would be outside the defined right-of-way. Because archaeological sites sometimes include buried components, ground-disturbing actions could uncover previously unidentified cultural materials. If cultural resources were encountered, a qualified archaeologist would participate in directing activities to ensure that the resources would be properly protected or the impact mitigated. DOE would use procedures to avoid or reduce direct impacts to cultural resources in construction areas where surface-disturbing activities would occur (see Chapter 9).

Indirect impacts, such as non-project-related disturbances of archaeological sites by purposeful or accidental actions of project employees, could occur from construction activities as a result of increased access and increased numbers of workers near cultural resource sites. These factors would increase the probability for either intentional or inadvertent indirect impacts to cultural resources. Section 6.3.2.2 discusses potential impacts specific to each corridor.

Systematic studies would be completed for a selected corridor to identify sites, resources, or areas that might hold traditional value for Native American peoples or communities. Two of the corridors (Caliente and Carlin) could affect as-yet unidentified resources because they could pass through the Timbisha Shoshone Trust Lands parcel near Scottys Junction. If sites or resources important to Native Americans were discovered in the future, either in or near an identified right-of-way, adverse effects could occur through direct means, such as construction activities, or indirectly through visual or auditory (sound and vibration) impacts.

In the viewpoint of Native Americans, the construction and operation of a branch rail line would constitute an intrusion on the holy lands of the Southern Paiute and Western Shoshone. In addition, some corridors pass through or near several significant places (see Chapter 3, Section 3.2.2.1.5). The American Indian Writers Subgroup has commented that the overall significance of these places and potential impacts from operation of a rail line on them cannot be fully understood until DOE has identified the rail alignment and completed ethnographic field studies and consultations (DIRS 102043-AIWS 1998, p. 4-6). If DOE selected a rail corridor, it would initiate additional engineering and environmental studies (including cultural resource surveys), conduct consultations with Federal agencies, the State of Nevada, and tribal governments, and perform additional National Environmental Policy Act reviews as a basis for final alignment selection and construction. DOE would address the mitigation of potential impacts to archaeological and historic sites during the identification, evaluation, and treatment planning phases of the cultural resource surveys.

Operations. No additional direct or indirect impacts would be likely at archaeological and historic sites from the operation of a branch rail line. However, if Native Americans identified specific concerns during the preconstruction consultations described above, DOE would address them at that time.

6.3.2.1.6 *Common Rail Occupational and Public Health and Safety Impacts*

Incident-Free Transportation. Incident-free impacts of rail transportation in Nevada would be unique for each of the five Nevada rail transportation implementing alternatives; these are discussed for each implementing alternative in Section 6.3.2.2. Incident-free impacts to hypothetical maximally exposed individuals would be similar among the Nevada rail transportation implementing alternatives. Table 6-21 lists the impacts to hypothetical maximally exposed individuals in Nevada who would be exposed to all rail shipments along a branch rail line. Appendix J, Section J.1.3.2.2 describes assumptions for estimating doses to maximally exposed individuals along routes in Nevada.

Table 6-21. Estimated doses and radiological impacts to maximally exposed individuals for Nevada rail implementing alternatives.[a,b]

Individual	Dose (rem)	Probability of latent cancer fatality
Involved workers		
Inspector	34	0.012
Railyard crew member	4.2	0.002
Public		
Nevada resident along route (rail)[c]	0.002	0.0000008
Person in traffic jam (legal-weight truck)[d]	0.02	0.000008
Person at service station (legal-weight truck)[e]	0.08	0.00004
Resident near rail stop	0.29	0.0001

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operation.
c. This represents a Nevada resident approximately 30 meters (98 feet) from the branch rail line. See Appendix J, Section J.1.3.2.2.
d. Person in a traffic jam is assumed to be exposed one time only.
e. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce doses to members of the public to below 100 millirem per year.

Accidents. Accident risks and maximum reasonably foreseeable accidents for rail shipments of spent nuclear fuel and high-level radioactive waste would be common to the Nevada rail transportation implementing alternatives. This section, therefore, discusses these risks.

Table 6-22 lists accident risks for transporting spent nuclear fuel and high-level radioactive waste in Nevada for the five Nevada rail transportation implementing alternatives. The data show that the risks, which are listed for 24 years of operations, would be low for each alternative. These risks include risks associated with transporting 1,079 legal-weight truck shipments made from the commercial sites that could not load rail casks while operational. Small variations in the risk values, principally evident for the Jean branch rail line, are a result of risks that would be associated with transporting rail casks arriving from the east on the Union Pacific Railroad's mainline through the Las Vegas metropolitan area. The values that would apply for a Valley Modified or Caliente-Chalk Mountain branch line would be lower

Table 6-22. Estimated health impacts[a] to the public from potential accident scenarios for Nevada rail implementing alternatives.

Risk	Caliente	Carlin	Caliente-Chalk Mountain	Jean	Valley Modified
Radiological accident risk[b]					
Dose risk (person-rem)	0.0017	0.0026	0.0017	0.0071	0.0021
LCFs[c]	0.0000009	0.0000013	0.0000009	0.000004	0.000001
Traffic fatalities	0.07	0.09	0.05	0.06	0.05

a. Data are reported for 24 years of operations.
b. In this table, radiological accident dose risk is the sum of the products of the probabilities (dimensionless) and consequences (in person-rem) of all potential transportation accidents. This sum is converted to latent cancer fatalities using the conversion factor of 0.0005 latent cancer fatality per person-rem.
c. LCF = latent cancer fatality.

because of a shorter corridor (Valley Modified), or a more remote and mid-length corridor (Caliente-Chalk Mountain).

Consequences of Maximum Reasonably Foreseeable Accidents. The national transportation analysis evaluated impacts of maximum reasonably foreseeable accidents (see Section 6.2.4.2).

6.3.2.1.7 *Common Rail Socioeconomics Impacts*

The common social and economic activities and changes associated with the construction of a branch rail line include:

- A period of brief, intense elevation in project-related employment followed by an abrupt decrease in associated employment opportunities as construction workers move to other projects.
- Transition of workers associated with construction of the branch rail line to other construction work in Nevada (if these workers did not move into positions associated with rail line operations).
- Population increases and then subsequent net declines as related employment requirements decline.
- A very slightly slower rate of growth in the level of employment as the economy moved from construction of a rail line to operations.
- A rise in the economic measures of real disposable income, Gross Regional Product, and State and local government expenditures during construction. Gross Regional Product, which is extremely sensitive to employment fluctuations, would be affected. Real disposable income, which consists of all forms of income including transfer payments (primarily unemployment compensation), is less responsive to changes in employment.

DOE performed detailed analyses for the corridors of the five branch rail line implementing alternatives. The results of these analyses, driven by the length of the corridor, are representative of the potential variations (options and alternates) of each corridor as listed in Appendix J, Section J.3.1.2. The lengths of the variations for each corridor are similar to the original corridor, as listed in Section 6.3.2.2.

Section 6.3.2.2 describes socioeconomic impacts for each particular implementing alternative.

6.3.2.1.8 *Common Rail Noise and Vibration Impacts*

Construction. For the most part, the rail corridors would pass through areas that are remote from human habitation. Thus, the potential for noise impacts from the construction of a branch rail line would be limited. Nonetheless, some people could be affected, including persons living near the corridor, using nearby recreational areas, seeking quiet and solitude at nearby locations, or living in nearby small rural communities. Noise from railroad construction could affect wild animals that inhabit the areas through which the corridors pass. However, construction noise would be transient and its sources would be gone when construction was complete.

Estimated noise levels for railroad construction would range from 62 to 74 A-weighted decibels (dBA) within 150 meters (500 feet) of the noise source and from 54 to 67 dBA at 600 meters (2,000 feet) (DIRS 104892-ICC 1992, p. 4-97). At distances up to 6 kilometers (3.7 miles), sound could exceed levels required for solitude (20 dBA). Trips to borrow and spoil areas would be another source of noise. Rail line construction would occur primarily during daylight hours, so nighttime noise would not be an issue unless there was a need to use accelerated construction to meet schedule constraints. There is a possibility that the construction of some structures associated with the rail line would occur during hours not in the normal workday, but the frequency and associated noise levels would be unlikely to be great. Because construction would progress along a corridor, construction noise would be transient in nearby communities. Noise levels could approach generally accepted limits for some residential and commercial areas, but this would be for a brief time. Because there are no permanent residences, construction noise would not be an issue for activities inside the boundaries of the Nellis Air Force Range, the Nevada Test Site, or the land withdrawal area that DOE analyzed for the proposed repository. Occupational Health and Safety Administration regulations (29 CFR) establish hearing protection standards for workers. DOE would meet those standards for workers involved in building a branch rail line.

Ground vibration from the construction of engineered structures, such as bridge foundations, could be discernible in some areas. The areas that would be affected would be determined by engineering surveys and detailed alignment analyses conducted after the selection of a corridor.

Operations. About five rail round trips (10 one-way trips) of spent nuclear fuel, high-level radioactive waste, or other material would occur weekly for 24 years on the branch rail line during normal operations. Noise from these trains could affect the same group of individuals and animals as construction of the rail line. To estimate noise impacts, the analysis assumed that trains would travel as fast as 80 kilometers (50 miles) an hour. The equivalent-continuous (average) sound level at 2,000 meters (6,600 feet) from a train consisting of two locomotives and 10 cars traveling at 80 kilometers an hour would be 51 dBA (DIRS 148155-Hanson, Saurenman, and Towers 1998, pp. 1 to 8), which is near the nighttime standard for residential areas (50 dBA). The estimated noise level at 200 meters (660 feet) would be 62 dBA (DIRS 148155-Hanson, Saurenman, and Towers 1998, pp. 1 to 8). This is slightly higher than the daytime standard for residential communities. In isolated regions, few people would be affected. In addition, trains traveling through or near communities would normally operate at reduced speed, so their noise levels would be lower. The combination of sparse population in the vicinity of the rail corridors, remoteness of a branch rail line from populated areas, substantial diminishing of the level of train noise with distance, and infrequent passage of trains indicates that the potential for noise impacts would be low for any of the corridors. In addition, in areas where a branch rail line or a variation could pass near a community, DOE would limit operating speeds to the extent necessary to ensure safety and noise levels below those listed in accepted noise standards.

DOE is not aware of traditional cultural properties or other areas along the rail corridors or variations where noise from trains or construction of a branch rail line could interfere with conditions necessary for meditation by, or religious ceremonies of, Native Americans. Similarly, there are no known ruins or other culturally sensitive structures that ground vibration could affect.

Ground vibration from trains using a branch rail line to Yucca Mountain would have the potential to cause impacts (see Section 6.3). Sections 6.3.2.2.1 to 6.3.2.2.5 discuss specific issues related to vibration for each corridor.

DIRS 155939-Nelson (2000, Appendix F, Table 1, p. 4) discussed vibration criteria for protection of historic buildings and presented data on vibration (peak particle velocity) for unit coal trains. Unit coal trains can consist of many loaded coal cars (usually more than 100) and multiple locomotives. The data (DIRS 155939-Nelson 2000, Appendix F) show that at distances of 100 meters (330 feet) from the track and for track not specially selected to reduce vibration, vibration from trains traveling at 56 kilometers (35 miles) per hour would be below the criterion for preservation of historic structures. Vibration from trains traveling on track that does not have rolling-mill undulation falls below the criterion at distances as close as 10 meters (33 feet) and speeds as high as 80 kilometers (50 miles) per hour. For shorter trains, such as those that would transport railcars with spent nuclear fuel and high-level radioactive waste to Yucca Mountain, attenuation of vibration with distance would be greater than that reported (DIRS 155939-Nelson 2000, p. 23).

6.3.2.1.9 *Common Rail Aesthetics Impacts*

Construction. The greatest impact on visual resources from the construction of a branch rail line would be the presence of workers, camps, vehicles, large earth-moving equipment, laydown yards, borrow areas, and dust generation. These activities, however, would have a limited duration (about 40 to 46 months depending on the corridor). The potential rail corridors and variations have all been affected to some extent by human activity, as described in Chapter 3, Section 3.2.2.1.1. Construction would progress along the selected corridor from its starting point to the proposed repository. Only a small portion of the overall construction time would be spent in one place; the exception to this would be places where major structures, such as bridges, would be built. In general, an individual construction camp would be active only for part of the construction period; after the completion of construction in an area, the camp would close.

Dust generation would be controlled by implementing best management practices such as misting or spraying disturbed areas. Construction activities would not exceed the criteria in the Bureau of Land Management Visual Resource Management guidelines (DIRS 101505-BLM 1986, all) with the exception of the Wilson Pass Option of the Jean Corridor. If the rail line crossed Class II lands, more stringent management and reclamation requirements would be necessary to retain as much as possible of the existing character of the landscape. The short duration of branch rail line construction activities, combined with the use of best management practices, would help mitigate the impacts of activities that could exceed the management requirements for Class II lands. Visual impacts to scenic quality Class C lands on the Nevada Test Site would not occur because of the remoteness and inaccessibility of the location. Impacts to the viewshed during construction of a branch rail line would include loss of vegetation in the areas surrounding the rail line. This loss could result in a long-term loss of viewshed along the corridor.

Operations. During proposed repository operations, visual impacts would be due to the existence of the branch rail line, access road, and borrow pits in the landscape and the passage of trains to and from the repository. The passage of 10 trains a week (5 coming and 5 returning) would have a small impact, temporarily attracting the attention of the casual observer. In limited access recreational areas classified as primitive or semiprimitive, the passage of these trains would have a greater impact. In addition, the noise generated by the trains would attract attention to them, temporarily increasing their impact on the scenic quality of the landscape. There would be no aesthetic impacts unique to any of the rail implementing alternatives.

6.3.2.1.10 *Common Rail Utilities, Energy, and Materials Impacts*

Construction. Because all five corridors would pass through sparsely populated areas with little access to support services, portable generators would provide electricity to support construction activities. The total fossil-fuel consumption in Nevada was about 3.8 billion liters (1 billion gallons) in 1996 (DIRS 148094-BTS 1997, Table MF-21). Fuel consumption estimates for construction of a branch rail line indicate low impacts compared to the statewide consumption of petroleum fuel.

Steel for rails and concrete, principally for rail ties, bridges, and drainage structures, and rock for ballast would be the primary materials consumed in the construction of a branch rail line. DOE would buy precast concrete railbed ties, culverts, bridge beams, and overpass components from a number of suppliers. Actual onsite pouring of concrete [less than 120,000 metric tons (132,000 tons)] would account for less than 30 percent of the total mass of concrete, which would be less than 0.5 percent of the concrete use in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all). Because DOE would buy precast concrete components from suppliers and because onsite concrete construction would involve a small amount of material for some abutments, the localized impact of concrete use in rail corridor construction would not be great for any of the corridors.

Because sources for rails and railroad ties are well established in the southwest and nationally, none of the quantities of materials required for constructing a rail line in Nevada would create demand or supply impacts in southern Nevada (DIRS 105033-Zocher 1998, all).

Impacts on utilities, energy, and materials differ among the implementing alternatives, as described in Section 6.3.2.2.

Operations. Impacts to utilities, energy, and materials from the operation of a branch rail line in Nevada would be small. Use of fossil fuel for train operations would be small. Chapter 10 discusses fossil fuel used for rail operations. No impacts would be unique to any of the branch rail line implementing alternatives.

6.3.2.1.11 *Common Rail Waste Management Impacts*

Construction. The construction of a branch rail line would require materials such as rail ties and steel; rock ballast; concrete; oils, lubricants, and coolants for heavy machinery; and compressed gasses (hazardous materials) for welding. DOE could order construction materials in correct sizes and number, resulting in very small amounts of waste (DIRS 152540-Hoganson 2000, all). In addition, much of the residual material from rail line construction would be saved for reuse or recycled. Construction of the branch rail line, service road, and access roads would require land clearing. Excavated soil would be used for fill as much as possible. Vegetation would be disposed of in accordance with State of Nevada requirements. Construction in any of the five corridors would result in small amounts of waste that would require disposal. Wastes would consist of construction debris such as banding material that bound ties and rails (DIRS 152540-Hoganson 2000, all) that DOE would dispose of in permitted landfills. Hazardous waste such as lubricants and solvents, if any, would be shipped to a permitted hazardous waste treatment and disposal facility.

Sanitary solid waste and sanitary sewage from flush toilets and showers would be generated in construction camps. The estimated peak annual generation would be 940 metric tons (1,000 tons) of sanitary solid waste and 37 million liters (10 million gallons) of sanitary sewage. The solid waste would be disposed of in a permitted landfill. Nevada has 24 operating municipal solid waste landfills (DIRS 155564-NDEP 2001, p. 1) with a combined capacity to accept 11,000 metric tons (12,000 tons) of waste per day (DIRS 155563-NDEP 2001, landfill inventory). In 2000, approximately 3.5 million metric tons (3.9 million tons) of sanitary solid waste were disposed of in Nevada (DIRS 155565-NDEP 2001, Section 2.1), so the construction camp waste would add approximately 0.03 percent. The sanitary sewage could be treated in an onsite treatment facility for which the contractor had obtained the necessary permits. In addition, a commercial vendor would provide portable restroom facilities where needed and manage the sanitary sewage.

All waste would be handled in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts from construction to plants, animals, soils, water resources, and air quality inside or outside the region of influence.

Operations. The use of a branch rail line in any of the five corridors would result in wastes from the maintenance of rolling and stationary railroad equipment and track. These wastes would include lubricants from equipment and machinery; solvents, paint, and other hazardous material; sanitary waste; and industrial wastes typical for operations of a small branch rail line. Operational wastes would include those generated during equipment maintenance. Maintenance of each locomotive would generate about 420 liters (110 gallons) of waste oil (DIRS 155559-Best 2001, all) that would be reclaimed rather than disposed. Worn or damaged parts and components would be repaired or remanufactured and returned to use. Routine maintenance of newer model rail cars would consist primarily of inspection and replacement of worn or damaged components. However, these cars are designed to last many years. In addition, sealed components would minimize the need for lubrication (DIRS 155558-Hoganson 2001, all). Routine maintenance and repair of rolling equipment would be performed at maintenance and repair yards operated by an independent contractor. Wastes from the maintenance of fixed rail line equipment such as signals and rail crossings would be minimal (DIRS 155560-Hoganson 2001, all). Crossties, ballast, rails, and bridges would be unlikely to require replacement before 2033 (DIRS 152540-Hoganson 2000, all). The management and disposition of operational wastes would comply with applicable environmental, occupational safety, and public health and safety regulations. Wastes would be handled such that adverse impacts from rail corridor operation waste to plants, animals, soils, air quality, and water resources along the right-of-way would be minimized.

There would be no waste management impacts unique to any of the branch rail line implementing alternatives.

6.3.2.2 Impacts Specific to Individual Rail Corridor Implementing Alternatives

6.3.2.2.1 *Caliente Corridor Implementing Alternative*

The Caliente Corridor would originate at an existing siding to the Union Pacific mainline railroad at Eccles siding near Caliente, Nevada (Figure 6-15). The corridor travels west, traversing the Chief, North Pahroc, Golden Gate, and Kawich Mountain Ranges. The Caliente and Carlin corridors converge near the northwest boundary of the Nellis Air Force Range. Past this point, the corridors are identical. The Caliente Corridor is 513 kilometers (319 miles) long from the Union Pacific line connection to the Yucca Mountain site. Variations of the route range from 512 to 553 kilometers (318 to 344 miles). Figure 6-15 shows this corridor, along with possible variations identified by engineering studies (DIRS 131242-CRWMS M&O 1997, all). The corridor variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-15. With the exception of the differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible variations.

Construction of a branch rail line in the Caliente corridor would require approximately 46 months. Construction would take place simultaneously at multiple locations along the corridor. An estimated six construction camps at roughly equal distances along the corridor would provide temporary living accommodations for construction workers and construction support facilities. A train would take about

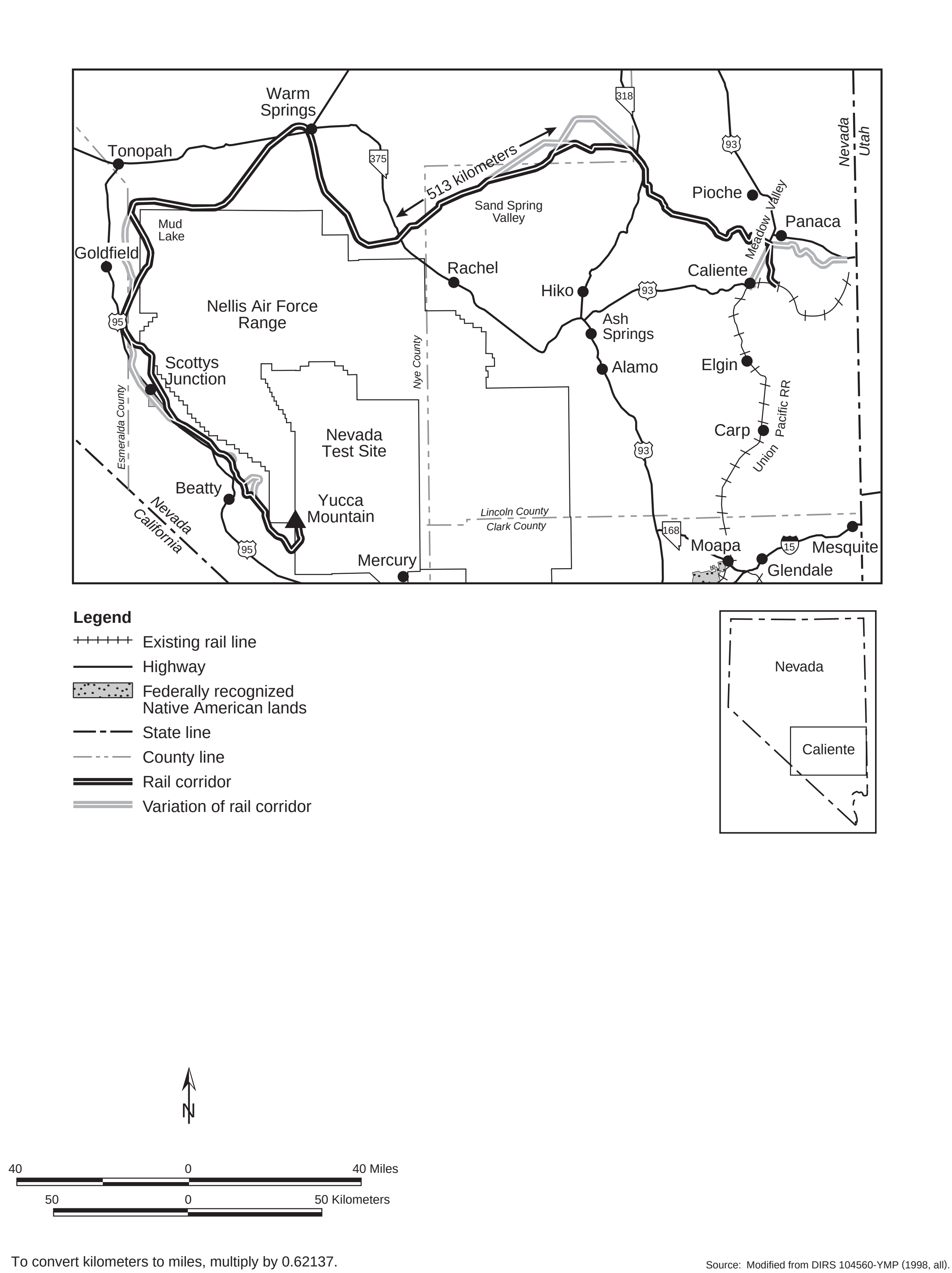


Figure 6-15. Caliente Corridor.

10 hours to travel from the junction with the Union Pacific mainline to a Yucca Mountain Repository on a Caliente branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). The estimated life-cycle cost of constructing and operating a branch rail line in the Caliente Corridor would be $880 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to air quality, aesthetics, and waste management would be the same as those described in Section 6.3.2.1 and are not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.1.1 Caliente Rail Land Use and Ownership

Table 6-23 summarizes the amount of land required for the Caliente corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-24 summarizes the amount of land required for the Caliente Corridor variations and its ownership.

Table 6-23. Land use in the Caliente Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	513	512 - 553
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	205 (100)	205 - 221
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	188 (92)[e]	188 - 216
Air Force	10.9 (5.3)	0 - 10.9
DOE	4.6 (2.3)	4.6 - 4.6
Private	0.9 (0.46)	0.9 - 2.5
Tribal	None	0 - 1.6
Land area in 60-meter[f] right-of-way *(square kilometers)*	30.7	30.7 - 33.2
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	14.7	14.7 - 15.9
Outside 60-meter right-of-way	3.6	3.6 - 3.9

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. Percentages do not total 100 due to rounding.
f. 60 meters = 200 feet.

Construction. This corridor crosses several telephone, pipeline, highway, and power line rights-of-way, areas designated as available for sale or transfer, and oil and gas leases (DIRS 104993-CRWMS M&O 1999, Table 2, p. 10 and Table 3, p. 11). The corridor crosses Bureau of Land Management lands used for recreation, nine grazing allotments (Bennett Springs, Highland Peak, Black Canyon, Reveille, Ralston, Stone Cabin, Montezuma, Magruder Mountain, and Razorback), and seven wild horse and burro herd management areas. Section 6.3.2.1 discusses impacts common to all rail implementing alternatives. This section discusses impacts unique to a branch rail line in the Caliente Corridor.

The corridor passes just east of the Weepah Spring Wilderness Study Area and just north of the Worthington Mountains Wilderness Study Area. It also passes near the Kawich Wilderness Study Area and crosses a portion of the South Reveille Wilderness Study Area. The Kawich Area in the Kawich Range and the South Reveille Area in the Reveille Range and along Reveille Valley form a narrow corridor through which the Caliente Corridor passes. A portion of the Kawich and South Reveille Ranges have Bureau of Land Management Class II aesthetic classifications. Construction activities in the vicinity of a Wilderness Study Area could affect the experience in the wilderness environment. As indicated in Appendix J, Section J.3.1.2, the White River Alternate would be more distant from the Area. This route

Table 6-24. Possible variations in the Caliente Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Ownership in variation [square kilometers (percent)] Bureau of Land Management	Private	Tribal
Eccles Option	16.7	6.7	6.3 (95)	0.4 (5)	--[e]
Caliente Option	17.2	6.9	6.2 (90)	0.69 (10)	--
Crestline Option	37.8	15.1	14.5 (95.9)	0.6 (4.1)	--
White River Alternate	47.5	19	18.98 (99.9)	0.02 (< 0.1)	--
Garden Valley Alternate	37.7	15.1	15.1 (100)	0	--
Mud Lake Alternate	(f)	(f)	(f)	--	--
Goldfield Alternate	45.8	18.3	17.6 (96)	0.7 (4)	--
Bonnie Claire Alternate	42.2[g]	16.9	14.8 (87.4)	0.5 (3)	1.6 (10)
Oasis Valley Alternate	5.57	2.2	2.0 (89)	0.2 (11)	--
Beatty Wash Alternate	23.0	9.2	9.2 (100)	0	--

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. NA = not applicable; length included in total corridor distance.
e. -- = none.
f. Mud Lake Alternate on Bureau of Land Management land included in other variations.
g. Includes 4.5 kilometers (2.8 miles) through Timbisha Shoshone Trust Lands.

variation would cross a small additional amount of private property. Impacts of constructing a branch rail line between the Kawich and South Reveille Areas would be less if DOE implemented Bureau of Land Management Class II requirements for building in these areas.

The Bonnie Claire Alternate of this corridor, in the vicinity of Scottys Junction, would pass through and bisect an 11.3-square-kilometer (2,800-acre) portion of the Timbisha Shoshone Trust Lands (DIRS 155930-Reynolds, Pool, and Abbey 2001, all). Bisecting this parcel could limit its proposed use, which includes tourism and housing for the Timbisha Shoshone.

If the Bonnie Claire Alternate was not used, the corridor would encroach on the Nellis Air Force Range (also known as the Nevada Test and Training Range). In addition, the Mud Lake Alternative would encroach on the Range. The U.S. Air Force has noted the potential for safety risks of crossing lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. For each of the sections that could enter the Nellis Range, DOE has identified a corridor variation that would avoid the potential land-use conflict (see Appendix J, Section J.3.1.2).

If DOE decided to build and operate a branch rail line in the Caliente Corridor, it would consult with the Bureau of Land Management, the U.S. Air Force, and other affected agencies and Native American governments to help ensure that it avoided or mitigated potential land-use conflicts associated with the alignment of a right-of-way. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range.

The presence of a rail line could influence future development and land use along the railroad in the communities of Beatty, Caliente, Goldfield, Scottys Junction, and Warm Springs (that is, zoning and land use might differ depending on the presence or absence of a railroad), as well as a potential Timbisha Shoshone community at their Trust Lands parcel near Scottys Junction.

Operations. DOE expects operations along the Caliente Corridor to cause fewer impacts than the construction phase of the project.

The operation of a rail line in the vicinity of the Weepah Spring Wilderness Study Area could affect the experience of visitors to the Area. The White River Alternate would not pass near the Area, as indicated in Appendix J, Section J.3.1.2. The proximity of an operational rail line to the Kawich and South Reveille Wilderness Study Areas probably would affect these areas by drawing attention to the rail line during operational or maintenance activities.

The operation of a rail line along the Bonnie Claire Alternate could limit or potentially enhance economic development in the Timbisha Shoshone Trust Lands parcel and could limit the use for housing by restricting access. The alternate currently passes almost directly through the center of the parcel.

6.3.2.2.1.2 Caliente Rail Hydrology

Surface Water

Surface-water resources along the Caliente Corridor are discussed in Chapter 3, Section 3.2.2.1.3, and summarized in Table 6-25. The table indicates that the number of surface-water resources in the vicinity of the corridor could vary if DOE used corridor variations, but only by small numbers. In fact, the Caliente Corridor has the smallest number of nearby water resources with the possible exception of the Oasis Valley Alternate. This alternate would be farther away from one identified spring such that the spring's location would no longer be within the 400-meter (0.25-mile)-wide corridor. The spring would, however, still be within 1 kilometer (0.6 mile) of the corridor. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface water, or the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-25. Surface-water resources along Caliente Corridor and its variations.[a,b,c]

	Resources in 400-meter[d] corridor			Resources outside corridor within 1 kilometer[e]		
Description	Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
Caliente Corridor	1	3	--[f]	5	--	--
with Crestline Option	1	3	--	7	--	--
with Caliente Option	2	3	--	7	--	--
with Goldfield Alternate	1	3	--	7	--	--
with Oasis Valley Alternate	--	3	--	6	--	--

a. Source: reduced from tables in Chapter 3, Section 3.2.2.1.3.
b. Resources are the number of locations; that is, a general location with more than one spring was counted as one water resource.
c. Resources shown for variations are for the entire corridor with only the identified changes. Variations not listed (White River Alternate, Garden Valley Alternate, Mud Lake Alternate, Bonnie Claire Alternate, and Beatty Wash Alternate) are not associated with any identified water resources, nor would they avoid any resources along the corridor.
d. 400 meters = about 1,300 feet.
e. 1 kilometer = 0.6 mile.
f. -- = none.

Flood zones identified along the Caliente Corridor and its variations are listed in Table 6-26. As indicated in the table's footnotes, the 100-year flood zone information is summarized from Federal Emergency Management Agency maps, which provide coverage for about half the corridor's length. Based on the available data, this corridor would cross nine different 100-year flood zones or flood zone groups between its beginning near Caliente and when it enters the Nevada Test Site. None of the variations would change this number notably. Use of the Crestline Option would decrease the number of flood zones by one, and the other applicable variations would leave the number unchanged or increased by one. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Table 6-26. 100-year flood zones crossed by the Caliente Corridor and its variations.[a,b]

Rail corridor portion	Crossing distance (kilometers)	Flood zone feature(s)	Avoided by variation (Yes or No)
Eccles Siding to Meadow Valley	0.2[c]	Clover Creek (intermittent)	Y-1
	0.8[c]	Meadow Valley Wash (wet)	Y-1, 2
Meadow Valley Wash to Sand Spring Valley	0.5[c]	White River (intermittent)	N
Sand Spring Valley to Mud Lake	1.1	Unnamed drainage gully on FEMA map in East/Central Nye County; crosses twice (dry)	N
	17.5	Mud Lake basin and drainage tributaries (normally dry)	N
Mud Lake to Yucca Mountain	0.8	Unnamed washes to the north and south of Ralston (dry)	N
	0.3	Tolicha Wash (intermittent)	Y-7
	1.1	Amargosa River (wet in sections, intermittent in others)	Y-8
	0.1	Beatty Wash (intermittent)	Y-9
Variations			
1. Crestline Option	0.8	Crosses Meadow Valley Wash (wet)	
2. Caliente Option	0.8	Crosses Meadow Valley Wash (wet)	
	0.2	Crosses Clover Creek (intermittent)	
	0.9	Crosses Meadow Valley Wash (wet) three times, rail corridor runs adjacent to Meadow Valley Wash. Passes in and out of flood zone	
3. White River Alternative	None	Located to the north of the corridor	
4. Garden Valley Alternative	None	Located to the north of the corridor	
5. Mud Lake Alternative	3.1	Crosses a larger amount of the Mud Lake flood zone (3.1 kilometers vs. 1.8 kilometers for the corridor)	
6. Goldfield Alternative	None	Located to west of corridor.	
7. Bonnie Claire Alternative	1.3	Crosses an unnamed wash south of Ralston	
	0.7	Crosses Tolicha Wash (intermittent)	
8. Oasis Valley Alternative	1.0	Crosses Amargosa River (wet in segments, intermittent in others)	
9. Beatty Wash Alternative	0.1	Crosses Beatty Wash (intermittent)	

a. Areas where natural floodwater movement might be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Lincoln and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. About 47 percent of the Caliente Corridor is not available on maps, due primarily to limited coverage in Lincoln County, the Nellis Air Force Range, and the Nevada Test Site.

c. Projected from limited data. The specific area is not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.

d. Certain 100-year flood zones can be avoided by alternate corridor segments. These are identified with a "Y" (yes) and a number representing the specific variations from the second half of the table that avoids the specific flood zone. The same flood zone could be crossed by the corridor and its variations at different locations. In such cases, the feature will be marked "Avoided" for the corridor, but will appear again for the variation.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (see Chapter 3, Section 3.2.2.1.3, for estimated perennial yields for the hydrographic areas over which a branch rail line in the Caliente Corridor would pass).

HYDROGRAPHIC AREA

The Nevada Division of Water Planning has divided the State into groundwater basins, or *hydrographic areas*. These areas are used in the management of groundwater resources. Hydrographic areas are generally based on topographic divides (that is, they typically comprise a valley, a portion of a valley, or a terminal basin), but can also be based on administrative divisions. The State classifies a hydrographic area as a Designated Groundwater Basin when the permitted water rights (or appropriations) approach or exceed the area's estimated perennial yield and the water resources are depleted or require additional administration. The Division of Water Planning's home page *http://www.state.nv.us/cnr/ndwp* identifies the hydrographic areas that are Designated Groundwater Basins.

The amount of water needed for the construction of a branch rail line in the Caliente Corridor for soil compaction, dust control, and workforce use would be about 880,000 cubic meters (710 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 64 wells installed along the rail corridor. The average amount of water withdrawn from each well would be approximately 14,000 cubic meters (11 acre-feet). Most (91 percent) of the water need would be for use in the compaction of fill material. The estimate of fill quantities needed for construction would change if variations were used. However, no single variation applicable to the Caliente Corridor would increase the estimate of water demand by more than 5 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the Caliente rail corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting water resources or requiring additional administration. Table 6-27 summarizes the status of the hydrographic areas associated with the Caliente Corridor and the approximate portion of the corridor that would pass over Designated Groundwater Basins. Use of corridor variations would make no notable difference in the portion of the corridor that crosses Designated Groundwater Basins.

Table 6-27. Hydrographic areas along Caliente Corridor and its variations.

		Designated Groundwater Basins	
Corridor description	Hydrographic areas	Number	Percent of corridor length
Caliente Corridor	17	6	40
Variations[a]	16 to 18	6	40

a. Several of the variations would involve small changes in the hydrographic areas crossed or the crossing distances. However, all (Caliente Option, Crestline Option, White River Alternate, Garden Valley Alternate, Mud Lake Alternate, Goldfield Alternate, Bonnie Claire Alternate, and Oasis Valley Alternate) would cross the same six Designated Groundwater Basins which, rounded to the nearest 10 percent, would represent the same portion of the total corridor.

The withdrawal of about 14,000 cubic meters (11 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente Corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 64 wells along the corridor would mean that many hydrographic areas would have multiple wells. As Table 6-27 indicates, about 40 percent of the corridor length would be over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Caliente Corridor would require about 47,000 tanker-truck loads of water or about eight truckloads each day for each work camp along the corridor. Again, water obtained from permitted sources, which would be within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. There would be no changes in recharge beyond those at the completion of construction.

6.3.2.2.1.3 Caliente Rail Biological Resources and Soils

Construction. The construction of a rail line in the Caliente Corridor including possible variations (see Appendix J, Section J.3.1.2) would disturb approximately 18 square kilometers (4,500 acres) of land (Table 6-23). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Areas within 12 of the land-cover types identified in the State of Nevada (DIRS 104593-CRWMS 1999, pp. C1 to C5) would be affected by construction of a branch rail line in the Caliente Corridor (see Table 6-28). The greatest amounts of disturbance would occur in the salt desert scrub and sagebrush land-cover types, but would involve less than 0.001 percent of the existing area of Nevada in those land-cover types. The 0.001 fraction that would be disturbed for each cover type would be very small. The disturbance would have no discernible impact on the availability of habitat in any cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to the unvaried corridor.

Table 6-28. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Caliente Corridor.[b,c]

Land-cover type	Percent of corridor length	Area disturbed	Area in Nevada	Percent disturbed
Agriculture	0.3	0.05	5,200	0.001
Blackbrush	0.1	0.02	9,900	<0.001
Creosote-bursage	6.0	1.1	15,000	0.007
Grassland	0.2	0.04	2,800	0.001
Greasewood	0.4	0.07	9,500	<0.001
Hopsage	2.0	0.36	630	0.06
Juniper	0.3	0.05	1,400	0.003
Mojave mixed scrub	4.5	0.82	5,600	0.01
Pinyon-juniper	0.0	0	15,000	0.00
Playa	0.1	0.02	7,000	<0.001
Sagebrush	30	5.4	67,000	0.01
Sagebrush/grassland	0.3	0.05	52,000	<0.001
Salt desert scrub	56	10	58,000	0.02
Urban		ND[d]	2,400	ND

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.

About 50 kilometers (31 miles) along the southern end of the corridor, including variations in this area, is in desert tortoise habitat. Assuming that a maximum of about 0.06 square kilometer (15 acres) of land would be disturbed for each kilometer of rail line in this area, construction activities would disturb as much as 3 square kilometers (740 acres) of desert tortoise habitat, none of which is classified as critical habitat. In addition, these activities could kill individual desert tortoises; however, their abundance is low in this area (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few. Relocation of tortoises along the route prior to construction would minimize losses of individuals. The presence of the branch rail line could interfere with the normal movements of individual tortoises. DOE would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) regarding this species if it selected this corridor and would implement all terms and conditions required by the Fish and Wildlife Service.

Although the southwestern willow flycatcher occurs near some portions of the corridor, including the variations, there is no suitable habitat of dense riparian vegetation for this Federally endangered species in the Caliente Corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The only other Federally listed species near the corridor and its variations is the Railroad Valley springfish (Federally threatened), which has been found about 3 kilometers (1.9 miles) north of the corridor, and it should not be affected. The Eccles, Crestline, or Caliente variations of this corridor cross a portion of the Meadow Valley Wash, which is habitat for an unnamed subspecies of the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker, both of which are sensitive species. Construction of a branch rail line in this corridor could temporarily affect populations of these fish by increasing the sediment load in the wash during construction. Four other special status species occur along this corridor and its variations but could be avoided during land-clearing activities (DIRS 104593-CRWMS M&O 1999, p. 3-23) and, therefore, would not be affected.

One population of the Nevada sanddune beardtongue, a sensitive plant species, occurs within the 400-meter (0.25-mile) corridor and could be directly or indirectly affected by land-clearing activities and construction of the branch rail line. The location of this population would be identified through surveys before these activities, and disturbance of the plants would be avoided if possible.

In addition, there are six known populations of four sensitive plant species outside the 400-meter (0.25-mile) corridor, but within 5 kilometers (3 miles). Several additional populations of these four species and one other sensitive plant species occur within 5 kilometers of one or more of the variations listed in Appendix J, Section J.3.1.2. One population of one species (Needle Mountain milkvetch) outside the 400-meter corridor would be avoided by the Caliente Option and three populations of this species would be avoided by the Crestline Option. DOE anticipates that corridor activities would not affect these populations because land disturbance would not extend to these areas and changes would be unlikely in the aquatic or soil environment as a result of construction or the long-term presence of a railroad.

The rail corridor crosses 15 areas designated as game habitat and 8 areas designated as wild horse and burro management areas (see Chapter 3, Section 3.2.2.1.4). Construction activities would reduce habitat in these areas. Depending on the variation, several other designated game habitat areas could be within 5 kilometers (3 miles) of a rail line in the Caliente Corridor. Wild horses, burros, and game animals near these areas during construction would be disturbed and their migration routes could be disrupted.

At least one group of springs and three stream or riparian areas are within the 400-meter (0.25-mile) corridor including its variations (Table 6-26). Although formal delineations have not been made, these springs and riparian areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. In addition, the corridor, including its variations, crosses a number of ephemeral streams that could be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. DOE anticipates some changes to local drainage along a branch rail line, and would design the rail line to accommodate existing drainage patterns.

In addition, as many as 25 known springs and riparian areas occur outside of the 400-meter (0.25-mile) corridor, but within 5 kilometers (3 miles) of the corridor, including its variations. Eight known populations of three sensitive animal species are associated with these aquatic resources. DOE anticipates that corridor activities would not affect these populations because land disturbance would not extend to these areas and these areas would not be disturbed during the construction or long-term presence of a railroad.

Construction activities would temporarily disturb about 18 square kilometers (4,500 acres) of soils in and adjacent to the corridor. The impacts to soils of disturbing 18 square kilometers along the 513-kilometer-(319-mile)-long corridor would be transitory and small. However, several soil characteristics could influence construction activities and the amount of disturbed area. Soils susceptible to water or wind erosion occur along much of the corridor and its variations as do soils exhibiting relatively high shrink-swell characteristics (see Chapter 3, Section 3.2.2.1.4). Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by winds. Erosion control during construction and revegetation, or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is, high) shrink-swell characteristics could influence the amount of disturbed area if soils from outside areas were brought in for replacement or mixing with the native soil.

As stated in Chapter 3, Section 3.2.2.1.4, the variations identified for the Caliente Corridor could avoid some biological resources, as listed in Table 6-29.

Table 6-29. Biological resources avoided by Caliente Corridor variations.[a]

Alignment variation resource	Occurrence of resource: For unvaried segment of corridor: In corridor[b]	Within 5 km[c]	Occurrence avoided by variation: In corridor	Within 5 km
Caliente variation[d]				
Sensitive species–Needle Mountain milkvetch	0	3	0	1
Springs or groups of springs	4	24	0	1
Crestline variation				
Sensitive species–Needle Mountain milkvetch	0	3	0	3
Springs or groups of springs	4	24	0	4

a. The only corridor variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25-mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.
d. Appendix J, Section J.3.1.2, lists variations for the Caliente Corridor implementing alternative.

6.3.2.2.1.4 Caliente Rail Cultural Resources

Construction. Site file searches for the Caliente Corridor and its variations (see Appendix J, Section J.3.1.2) yielded 97 recorded archaeological sites, 36 of which are either potentially eligible or have not been fully evaluated for the *National Register of Historic Places* (Chapter 3, Section 3.2.2.1.5). If DOE selected this corridor, it would conduct on-the-ground surveys of the 400-meter (0.25-mile)-wide corridor before and during construction activities to determine if construction of a branch rail line in this corridor could disturb sites or crush artifacts at archaeologic and historic sites.

At various points along the route, the Caliente Corridor and its variations intersect physical vestiges of historic railroads, including the Caliente and Pioche, Tonopah and Goldfield, and Las Vegas and Tonopah Railroads. The corridor also intersects the 1849 Jayhawker Emigrant Trail in Lincoln and Nye Counties. It passes close to three *National Register of Historic Places* properties—the Union Pacific Depot in Caliente (Caliente variation), the Tonopah Multiple Resource Area, and the Goldfield Historic District (Goldfield variation). However, the corridor and its variations passes these resources at a distance where adverse impacts would be unlikely. Southeast of Tonopah, the route passes through the former bombing range of the World War II Tonopah Army Air Station. Features related to that activity would be likely to occur on the landscape, but precise identification would not be possible until the completion of a cultural resource field inventory.

No areas or properties of interest to Native Americans have been identified and field-verified in the Caliente Corridor or its variations. However, the proposed right-of-way is near several potentially significant areas, including the Wild Horse and Willow Springs vicinity east of Goldfield (Caliente Corridor and Goldfield variation), the Oasis Valley north of Beatty (Oasis Valley Alternate), Crater Flat, and the Busted Butte-Fortymile Canyon area near the repository (DIRS 155826-Nickens and Hartwell 2001, all). In addition, the Bonnie Claire Alternate of the Carlin and Caliente Corridors passes through the land at Scottys Junction recently transferred to the Timbisha Shoshone Tribe.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.1.5 Caliente Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Caliente branch rail line would be small. The analysis evaluated the potential for impacts in terms of total reportable cases of injury and illness, lost workday cases, and fatality risks to workers and the public from construction and operation activities. Table 6-30 lists these results.

The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-31 lists these results.

Table 6-30. Impacts to workers from industrial hazards during rail construction and operations in the Caliente Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	110	95
Lost workday cases	55	52
Fatalities	0.2	0.3
Noninvolved workers		
Total recordable cases	6.7	5.4
Lost workday cases	2.5	2.0
Fatalities	0.01	0.01
Totals[d]		
Total recordable cases	120	100
Lost workday cases	57	54
Fatalities	0.2	0.3

a. Totals for 46 months of construction.
b. Totals for 24 years of operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Caliente Corridor. Table 6-32 lists the incident-free impacts, which include transportation along the Caliente Corridor and along railways in Nevada leading to a Caliente branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

6.3.2.2.1.6 Caliente Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Caliente Corridor.

Construction. The length of the Caliente Corridor—513 kilometers (319 miles)—is the most important factor for determining the number of workers that would be required. To construct a branch rail line in this corridor would require workers laboring approximately 2.8 million hours or 1,410 worker years during the 46-month construction period (DIRS 154822-CRWMS M&O 1998, all). The route would require six construction camps to house workers temporarily.

Employment

DOE anticipates that total (direct and indirect) employment in the region of influence attributable to the Caliente branch rail line would peak in the first year of construction, 2006, at about 842 workers. Clark County would gain about 664 workers and Nye County would gain 101. The increase in employment

Table 6-31. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction			
Material delivery vehicles	20,000,000	0.3	0.04
Commuting workers	85,000,000	0.8	0.11
Subtotals	*100,000,000*	*1.2*	*0.15*
Operations			
Commuting workers	68,000,000	0.7	0.09
Totals	***170,000,000***	***1.9***	***0.24***

a. To convert kilometers to miles, multiply by 0.62137.

Table 6-32. Health impacts from incident-free Nevada transportation for the Caliente Corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	810	850
Estimated LCFs[c]	0.02	0.32	0.34
Public			
Collective dose (person-rem)	7	12	19
Estimated LCFs	0.003	0.01	0.01
Estimated vehicle emission-related fatalities	0.0016	0.0056	0.0071

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.
c. LCF = latent cancer fatality.

represents less than 1 percent of the baseline employment in Clark and Nye Counties. The additional 77 workers would represent a 3.2-percent increase of the employment baseline for Lincoln County. Changes in the Lincoln County level of employment would be the result primarily of indirect employment created by the presence of the transient construction workers.

Employment of Caliente Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 827. The expected addition of 14,886 jobs in Clark County would be reduced by 788, and the expected growth of 330 jobs in Nye County would be reduced by 53. The expected growth of 24 jobs in Lincoln County would be supplemented by a net gain of 14. DOE anticipates that project-related workers not moving to Caliente Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence associated with the construction of a Caliente branch rail line would peak in 2009 at about 822 persons. About 728 individuals would live in Clark County, 64 in Nye County, and 29 in Lincoln County. The estimated population increase attributable to the rail construction in the three counties is less than 1 percent of each county's population baseline. Because the change in population in relation to the population baseline would be small and transient, impacts to housing or schools would be unlikely.

Economic Measures

The expected peak annual changes in economic measures in the region of influence attributable to the Caliente Corridor would be increases of $24.3 million in real disposable income in 2009; $40.3 million in Gross Regional Product in 2007; and $2.8 million in State and local expenditures in the final year of construction, 2009. Clark County would generate more than 94 percent of the Gross Regional Product, experience more than 94 percent of the increase in real disposable income, and absorb more than 83 percent of the increase in expenditures by State and local governments. Nye and Lincoln Counties would share the remainder. (All dollar values in this section are in 2001 dollars unless otherwise stated).

Construction-related impacts to real disposable income, Gross Regional Product, and State and local government expenditures would be a less-than-1 percent increase for Clark and Nye Counties. Although the estimated increase in Lincoln County's Gross Regional Product would be about 1.6 percent of the baseline in 2006, increases in Gross Regional Product during the other years of construction. The increases in real disposable income would be about 1.2 percent in 2006 and less than 1 percent in other years. Increases in State and local government expenditures during all years of construction would be less than 1 percent from the County's baselines.

Transition and Operations Period. Employment opportunities associated with the construction of the branch rail line would probably dissipate at the project's completion and reduce the region's employment by 46 positions annually for 4 years. However, Nye County would have a net gain of 6 jobs and Lincoln County would have a net gain of 56 employment positions above the baseline. The additional job gain in Lincoln County represents a 2.2-percent average increase over the employment baseline in the referenced 4-year period. The employment gain in Nye County would be less than 1 percent. Constructing and operating a Caliente branch rail line would contribute to the growth in residential population throughout the transition period and to the employment base after 2013.

Employment and Population

Estimated annual direct employment for Caliente branch rail line operations would be 47 workers. Increased employment in the three counties comprising the region of influence would average about 79 jobs annually over the 24-year operations period (2010 to 2033). DOE anticipates that, on average, approximately 56 of these individuals would work in Lincoln County, representing a 2.1-percent increase of the employment baseline for Lincoln County. Increases in Clark and Nye Counties would be less than 1 percent of the baselines. In the region of influence, the average change to population because of a Caliente branch rail line would be about 351 additional people. DOE anticipates that approximately 95 individuals probably would choose to live in Lincoln County, an addition of 2 percent of the population baseline. The impact due to increases in population in Clark and Nye Counties would be much less than 1 percent of the applicable baseline. Because the impacts to population and employment would be so small in Clark and Nye Counties, impacts to housing or schools would be unlikely in either county. As discussed in Chapter 3, Section 3.1.7.4, Lincoln County has a low occupancy rate for housing; therefore, the impact to Lincoln County's housing market would be very small despite a 2-percent increase in population. The annual impact to schools in Lincoln County resulting from the increase in population would average about 22 additional pupils.

Economic Measures

Within the three-county region of influence, the estimated greatest annual increase above the baseline in real disposable income attributable to operations would occur in 2033, the last year of operation, and would be $6.2 million; annual increases during the 24 years of operation would average $5.2 million. Increases in Gross Regional Product would average about $4.5 million. As discussed above, the region would experience a slower growth in employment for several years. In the case of the Caliente branch rail line, on average during operation, changes in real disposable income would exceed changes in Gross Regional Product. Annual State and local government expenditures during operations, averaging $1.8 million, would be much lower than those reported above for construction. Impacts to real disposable income, Gross Regional Product, and State and local government expenditures from the operation of a Caliente branch rail line would be less than 1 percent of the baseline for Clark and Nye Counties.

In Lincoln County, the impact of the change to the baseline in real disposable personal income and in government spending would be to increase levels by averages of 1.6 percent and 2.4 percent, respectively, for the duration of operations. Changes to the Gross Regional Product would average 2.6 percent above the baseline. Workers associated with operation of a Caliente rail line would purchase many goods and services in Lincoln County. These dollars would continue to circulate largely in the area, creating a positive economic impact.

DOE performed detailed analyses for the Caliente Corridor branch rail line implementing alternative. The results of the analyses are representative of the potential variations listed in Appendix J, Section J.3.1.2.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent (29 persons) during construction and by 6.9 (67 persons) percent during operations. Employment would rise by about 5 percent during construction and about 7.2 percent during operations.

6.3.2.2.1.7 Caliente Rail Noise and Vibration

Over most of its length, the Caliente Corridor passes through undeveloped land managed by the Bureau of Land Management, where human inhabitants are mostly isolated ranchers and persons involved with outdoor recreation. The Towns of Caliente and Panaca are near or along the eastern end of the corridor. The Caliente variation for connecting to the Union Pacific Railroad mainline would follow an old railroad bed through the center of the Town of Caliente. Corridor variations (see Appendix J, Section J.3.1.2) with the exception of Caliente are close enough to the rail line for noise impacts to be significant (Table 6-33). Noise levels in Caliente would not differ much from existing background noise levels associated with normal rail traffic through the community. Noise levels associated with waste shipments would occur at most three times a day and probably not within any given hour. Where the branch rail line passed through Caliente, train speed would be reduced for safety and noise levels would be minimized. There is one traffic crossing in the Town of Caliente where traffic could be delayed. Adverse community response to the added rail noise would be unlikely because of the long-term presence of railroad traffic in Caliente, the short trains associated with transport of waste shipments, and the low frequency of rail trips to and from the Yucca Mountain site.

Table 6-33. Estimated propagation of noise from the operation of waste transport train using two locomotives in communities near the Caliente Corridor.

Community	Distance (kilometers)[a]	Estimated noise (dBA)[b]
Caliente Option		
Caliente	0	>90 at 15 meters[c]
Panaca	6[d]	26.0
Crestline Option		
Panaca	4.5[d]	26.3
Eccles Option		
Caliente	6.5[d]	<26[e]
Tonopah	12[d]	<26
Goldfield	6.2[d]	<26
Beatty	9.6[d]	<26
Beatty Wash Alternate		
Beatty	11.2[d]	<26
Amargosa Valley	9.6[d]	<26

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
c. 15 meters = 49 feet.
d. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.
e. At these distances, the A-weighted sound pressure level is dominated by lower frequencies (lower than 63 Hertz) and would not be distinguishable from normal background levels of noise.

In addition to passing near communities, the Caliente Corridor, including its variations, would pass through areas with farms and ranches. Some rural residences could fall within the region of influence for noise. The corridor, except the Caliente Option that would pass through Caliente, would be at least 4 kilometers (2.5 miles) from every town or community along its length. The noise from trains in these remote communities would not exceed daytime or nighttime noise standards for residential areas (60 or 50 dBA, respectively). Similarly, there would be little potential for noise impacts from construction and operation activities.

The estimated population residing within 2 kilometers (1.2 miles) of the Caliente Corridor in 2035 would be about 350 persons.

The Caliente Corridor would pass within 1.9 kilometers (1.2 miles) of the border of the Timbisha Shoshone Homeland. The Bonnie Claire Alternate would pass through 4.1 kilometers (2.5 miles) of the Timbisha Shoshone Trust Lands parcel near the intersection of State Route 267 and U.S. Highway 95. Noise levels from trains passing through the homeland would be 90 dBA at 15 meters (49 feet) for the Bonnie Claire Alternate. At the closest point of the Caliente Corridor, the estimated noise levels would be 44 dBA. Ethnographic responses to noise have not been determined (see Section 6.1.2.5). However, the noise levels associated with the Caliente Corridor would be lower than those associated with the Bonnie Claire Alternate.

Vibration. With the exception of the historic railroad station in Caliente, which is near the existing Union Pacific Railroad mainline, a branch rail line in the Caliente Corridor would be distant from historic structures, ruins, and buildings. Therefore, vibration impacts would be unlikely except at the Caliente Rail Station. However, the vibrations added by the relatively few trains carrying spent nuclear fuel and high-level radioactive waste at slow speeds through Caliente would not add appreciably to the vibrations to which the station is exposed from commercial train traffic. The small number of trips (two per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.1.8 Caliente Rail Utilities, Energy, and Materials

Table 6-34 lists the use of fossil fuel and other materials for the construction of a Caliente branch rail line.

Table 6-34. Construction utilities, energy, and materials for a Caliente branch rail line.

Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)[c]
510 - 550	42 - 45	870 - 940	72 - 78	420 - 460

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.2 *Carlin Corridor Implementing Alternative*

The Carlin corridor originates at the Union Pacific main line railroad near Beowawe in north-central Nevada. Figure 6-16 shows this corridor along with possible variations identified by engineering studies (DIRS 131242-CRWMS M&O 1997, all). The variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-16. With the exception of the differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible variations.

The corridor travels south through Crescent, Grass, and Big Smoky Valleys, passing west of the City of Tonopah and east of the City of Goldfield. The corridor then travels south following and periodically

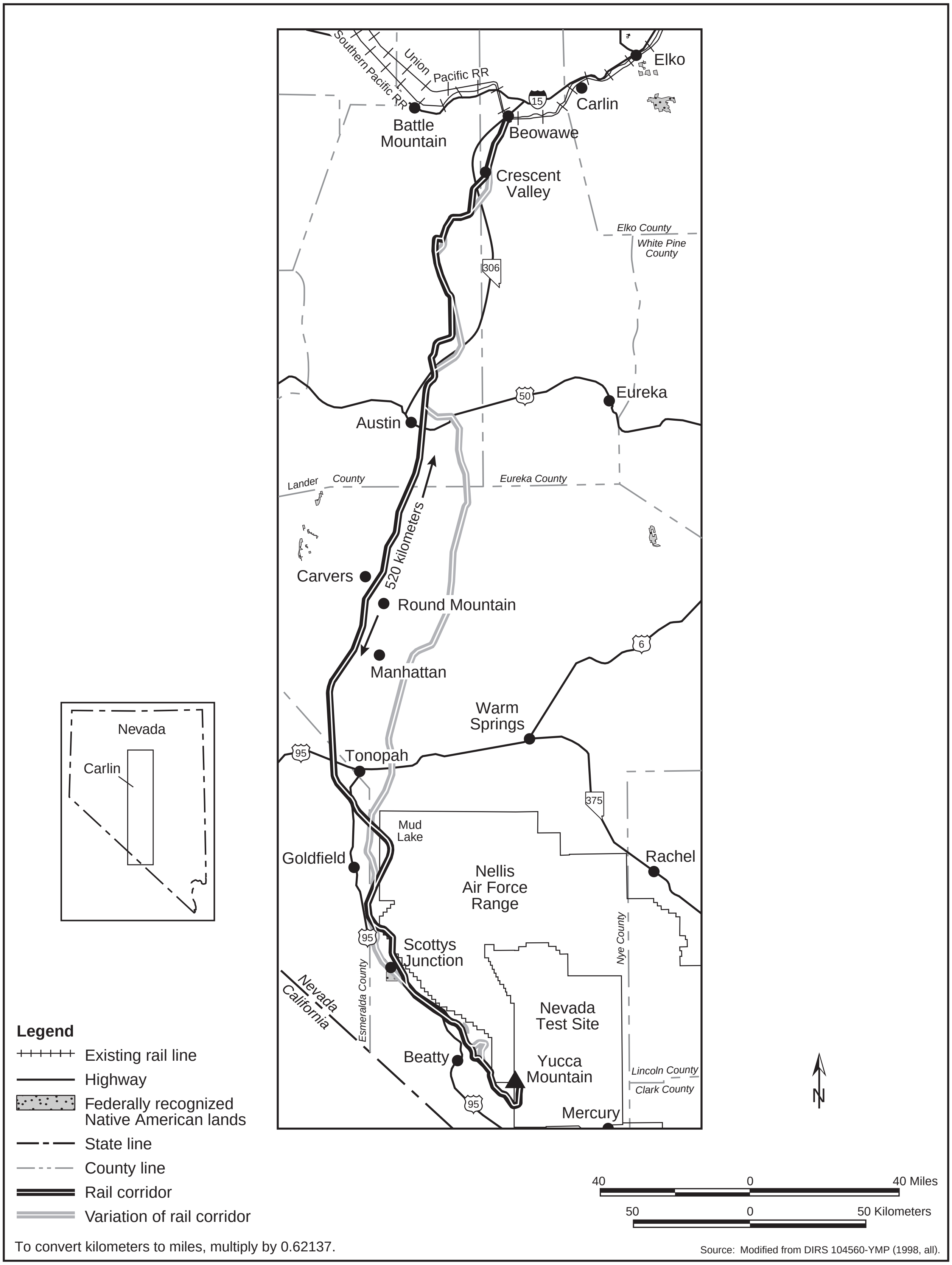


Figure 6-16. Carlin Corridor.

crossing the western boundary of the Nellis Air Force Range, passing through Oasis Valley and Beatty Wash. It travels along Fortymile Wash to the proposed repository location. The Carlin Corridor is about 520 kilometers (323 miles) long from its link with the Union Pacific line to the Yucca Mountain site. Variations of the route range from 513 to 544 kilometers (319 to 338 miles).

The construction of a branch rail line in the Carlin Corridor would require approximately 46 months. Construction would take place simultaneously at multiple locations along the corridor. DOE would establish an estimated five construction camps at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities. A train would take about 9 hours to travel from the junction with the Union Pacific mainline to the Yucca Mountain site on a Carlin branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Carlin Corridor would be about $821 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to air quality, aesthetics, and waste management would be the same as those common impacts discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.2.1 Carlin Rail Land Use and Ownership

Table 6-35 summarizes the amount of land required for the Carlin Corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-36 summarizes the amount of land required for the Carlin Corridor variations and its ownership.

Table 6-35. Land use in the Carlin Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	520	513 - 544
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	208 (100)	205 - 218
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	179 (86)	177 - 201
Air Force	11 (5.2)	0 - 10.9
DOE	4.6 (2.2)	4.6 - 4.6
Private	14 (6.7)	7.3 - 15.2
Tribal	None	0 - 1.6
Land area in 60-meter[e] *right-of-way (square kilometers)*	31.2	30.8 - 32.6
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	17	16.7 - 17.7
Outside 60-meter right-of-way	2.3	2.2 - 2.4

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. 60 meters = 200 feet.

Construction. The Carlin Corridor crosses various telephone, highway, and utility rights-of-way. The corridor also crosses a Desert Land Entry withdrawal, 12 Bureau of Land Management grazing allotments (Carico Lake, Dry Creek, Grass Valley, Kingston, Simpson Park, Wildcat Canyon, Big Smoky, Francisco, San Antone, Montezuma, Magruder Mountain, and Razorback) and six wild horse and burro herd management areas. Other areas crossed by the corridor include the Bates Mountain antelope release area,

Table 6-36. Possible variations in the Carlin Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Ownership in variation [square kilometers (percent)]		
			Bureau of Land Management	Private	Tribal
Crescent Valley Alternate	24.4	9.8	7.2 (77)	2.3 (23)	--[d]
Wood Spring Canyon Alternate	11.7	4.7	4.7 (100)	0	--
Rye Patch Alternate	35.3	14.1	14.1 (100)	0	--
Steiner Creek Alternate	41.5	16.6	16.6 (100)	0	--
Big Smoky Valley Option	197	78.9	78.9 (100)	0	--
Monitor Valley Option	225.4	90.2	90.2 (100)	0	--
Mud Lake Alternate	(e)	(e)	(e)	--	--
Goldfield Alternate	43.1	18.3	17.6 (96)	0.7 (4)	--
Bonnie Claire Alternate	42.2[f]	16.9	14.3 (87)[g]	0.4 (3)	1.6 (10)
Oasis Valley Alternate	5.57	2.2	2.0 (89)	0.2 (11)	--
Beatty Wash Alternate	23.0	9.2	9.2 (100)	0	--

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. -- = none.
e. Mud Lake Alternate included in other variations.
f. Includes 4.5 kilometers (2.8 miles) of Timbisha Shoshone Tribal land.
g. Includes 18 square kilometers (450 acres) of Timbisha Shoshone Tribal land.

three designated riparian habitats, and the Simpson Park habitat management area. It does not cross any oil or gas exploration and extraction areas. However, Bureau of Land Management lands are open to mineral and oil and gas exploration. The corridor passes through Bureau lands that are used for recreation, but does not pass through state or national forests. It does pass through areas adjacent to such facilities.

The construction of a branch rail line through Desert Land Entry withdrawal areas could affect the economic development of such properties by removing a portion of the lands and transferring it to DOE. If such property was divided, continued access to the property would be required. Construction impacts would be similar to those discussed in Section 6.3.2.1. As with the Caliente Corridor, the Bonnie Claire Alternate in the vicinity of Scottys Junction would pass through and divide an 11.3-square-kilometer (2,800-acre) portion of the Timbisha Shoshone Trust Lands (DIRS 155930-Reynolds, Pool, and Abbey 2001, all). The construction of a branch rail line in the Bonnie Claire Alternate could limit or potentially enhance economic development in the Timbisha Shoshone Trust Lands parcel and could limit the use for housing by restricting access.

The withdrawal of property from the private sector and the transfer of public lands would occur under existing government protocols. The withdrawal of lands from private ownership could impact area city and county economic expansion through the loss of tax revenues.

There are current mining operations in the Cortez Mine area of Crescent Valley. These operations, along with the historic mines in the area, make continued mining of this area a probability. Although the Carlin Corridor crosses no current leases, access through the valley could be affected for a short period during the construction of a branch rail line. The corridor also passes through areas of potential future exploration. The Crescent Valley Alternate (see Appendix J, Section J.3.1.2) passes just west of the Cortez Gold Mines. This corridor variation crosses an existing road right-of-way leading from the Gold Acres Mine to the ore mills at the Cortez mining facility. It also crosses a proposed pipeline right-of-way from the Cortez Gold Mine to the Dean Ranch. This pipeline would deliver water to the ranch (DIRS 155095-BLM 2000, all). Construction activities could deny or interfere with access to the milling facility at Cortez. The pipeline right-of-way would have to be modified to include DOE or the property rights would have to be transferred to DOE. Impacts to the road right-of-way would be slight if access to the area's mining facilities was maintained. The pipeline could require modifications to allow the building of a rail line through the right-of-way.

The Steiner Creek Alternate passes close to and might encroach on the Simpson Park Wilderness Study Area. Construction activities in the vicinity of a wilderness study area could affect the experience in the wilderness environment.

One segment of the Carlin Corridor and the Mud Lake Alternate would encroach on the Nellis Air Force Range (also known as the Nevada Test and Training Range). The U.S. Air Force has noted the potential for safety risks of crossing lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. For each of the sections that could enter the Nellis Range, DOE has identified a corridor variation that would avoid the potential land-use conflict (see Appendix J, Section J.3.1.2). If DOE decided to build and operate a branch rail line in the Carlin Corridor, it would consult with the Bureau of Land Management, the U.S. Air Force, and other affected agencies and Native American governments to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range.

The presence of a rail line could influence future development and land use along the railroad in the communities of Austin, Beatty, Carver's Station, Cortez, Crescent Valley, Manhattan, Round Mountain, Scottys Junction, and Tonopah (that is, zoning and land use might differ depending on the presence or absence of a railroad), as well as a potential Timbisha Shoshone community at their Trust Lands parcel near Scottys Junction.

Operations. DOE expects operations along the Carlin Corridor, including its variations, to cause fewer impacts than the construction phase of the project, even though the branch rail line would pass through areas of private ownership and a number of other unique areas (see Table 6-2 in Section 6.1.2.1). The presence of an operational rail line near the Simpson Park Wilderness Study area could detract from the wilderness experience. The operation of a branch rail line along the Bonnie Claire Alternate could limit economic development in the Timbisha Shoshone parcel and could limit the parcel's use for reservation housing by restricting access. The Bonnie Claire Alternate passes almost directly through the center of the parcel.

6.3.2.2.2.2 Carlin Rail Hydrology

Surface Water

Surface-water resources along the Carlin Corridor and its variations are discussed in Chapter 3, Section 3.2.2, and summarized in Table 6-37. As listed in the table, the number of surface-water resources in the vicinity of the corridor would change by small numbers if DOE used any of the variations. Both the Rye Patch and Oasis Valley Alternates would involve one less surface-water resource in the 400-meter (0.25-mile)-wide corridor, and a corresponding increase in the number of resources outside the corridor but within 1 kilometer (0.6 mile). As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface waters, and the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Flood zones identified along the Carlin Corridor and its variations are listed in Table 6-38. The Federal Emergency Management Agency maps from which DOE derived the flood zone information provided coverage for about 83 percent of the corridor's length. This corridor would cross 11 different 100-year

Table 6-37. Surface water resources along Carlin Corridor and its variations.[a,b,c]

Corridor description	Resources in 400-meter[d] corridor			Resources outside corridor within 1 kilometer[e]		
	Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
Carlin Corridor	1	5	--[f]	10	2	1
with Wood Spring Canyon Alternate	1	5	--	8	2	1
with Steiner Creek Alternate	1	5	--	10	1	1
with Rye Patch Alternate	1	4	--	11	3	1
with Monitor Valley Option	1	5	--	9	2	--
with Gold Field Alternate	1	5	--	12	2	1
with Oasis Valley Alternate	--	5	--	11	2	1

a. Source: Reduced from tables in Chapter 3, Section 3.2.2.1.3.
b. Resources are the number of locations; that is, a general location with more than one spring was counted as one water resource.
c. Resources shown for variations are for the entire corridor with only the identified variation changed. Variations not shown (that is, Crescent Valley Alternate, Mud Lake Alternate, Bonnie Claire Alternate, and Beatty Wash Alternate) are neither associated with any identified water resources, nor would they avoid any resources along the Corridor.
d. 400 meters = about 1,300 feet.
e. 1 kilometer = 0.6 mile.
f. -- = none.

flood zones or flood-zone groups before entering the Nevada Test Site. Eight of the 10 variations would change the number of flood zones crossed but, with one exception, changes would be up or down by one. The exception would be the Monitor Valley Option, which would increase the number of 100-year flood zones crossed by four. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (see Chapter 3, Section 3.2.2.1.3, for estimated perennial yields for the hydrographic areas over which the potential branch rail line in the Carlin Corridor passes).

The estimated amount of water needed for the construction of a branch rail line in the Carlin Corridor for soil compaction, dust control, and workforce use would be about 810,000 cubic meters (660 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 67 groundwater wells installed along the rail corridor. The average amount of water withdrawn from each well would be approximately 12,000 cubic meters (10 acre-feet). Most (91 percent) of the water would be used for compaction of fill material. The estimate of fill quantities for construction varies according to the variation. However, no single variation applicable to the Carlin Corridor would increase the estimate of water demand by more than 5 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting water resources or requiring additional administration.
Table 6-39 summarizes the status of the hydrographic areas associated with the Carlin Corridor, and the approximate portion of the corridor that passes over Designated Groundwater Basins. As listed in Table 6-39, use of the Monitor Valley Option would result in an approximate 20-percent decrease in the portion of the corridor crossing Designated Groundwater Basins.

Table 6-38. 100-year flood zones crossed by the Carlin Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Beowawe to Austin	4.0	Flood zone associated with Coyote Creek drainage (dry)	N
	1.6	Indian Creek (dry) and unnamed wash to the south	Y-1
	0.9	Unnamed Callaghan tributary, Skull and Callaghan Creeks (intermittent)	Y-3
	0.1	Rye Patch Canyon Creek (intermittent)	Y-4, 5
	1.4	Simpson Park Canyon Creek (intermittent) and Canyon Creek drainage (intermittent)	Y-4, 5
	1.4	Canyon Creek and Canyon Creek drainage (intermittent)	Y-5
Austin to Mud Lake	0.3	Peavine Creek tributary (intermittent)	Y-5
Mud Lake to Yucca Mountain	0.8	Unnamed washes to the north and south of Ralston (dry)	N
	0.3	Tolicha Wash	Y-8
	1.1	Amargosa River (wet in sections, intermittent in others)	Y-9
	0.1	Beatty Wash	Y-10
Variations			
1. Crescent Valley Alternate	2.0	Crosses Indian Creek (intermittent)	
	3.2	Crosses an unnamed wash to the south	
2. Wood Spring Alternate	None	Located to the west of the primary rail corridor	
3. Steiner Creek Alternate	4.9	Crosses Callaghan and Canyon Creeks (intermittent)	
4. Rye Patch Alternate	1.4	Crosses Canyon Creek and Canyon Creek drainage (intermittent)	
5. Monitor Valley Option[d]	0.6	Crosses Mosquito Creek (intermittent)	
	0.5	Crosses Corcoran Creek and Meadow Creek (intermittent)	
	1.5	Crosses Meadow Creek drainage; (dry)	
	0.6	Crosses Hunts Canyon Creek (intermittent)	
	0.2	Crosses Willow Creek (intermittent)	
	2.0	Crosses drainage areas approaching Mud Lake (dry)	
	5.7	Crosses drainage areas approaching Mud Lake (dry)	
	4.8	Crosses Mud Lake drainage (dry)	
6. Mud Lake Alternate	3.1	Crosses the Mud Lake flood zone	
7. Goldfield Alternate	None	Located to west of rail Corridor	
8. Bonnie Claire Alternate	1.3	Crosses an unnamed wash south of Ralston	
	0.7	Crosses Tolicha Wash (intermittent)	
9. Oasis Valley Alternate	1.0	Crosses Amargosa River (wet in segments, intermittent in others)	
10. Beatty Wash Alternate	0.1	Crosses Beatty Wash (intermittent)	

a. Areas where natural floodwater movement might be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Eureka, Lander, and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. About 17 percent of the primary Carlin Corridor is not available on Federal Emergency Management Agency maps, due primarily to limited coverage in Esmeralda County, the Nellis Air Force Range, and the Nevada Test Site.

c. To convert kilometers to miles, multiply by 0.62137.

d. Certain 100-year flood zones can be avoided by alternate corridor segments. These are identified with a “Y” (yes) and a number representing the specific alternate(s) from the second half of the table that avoids the specific flood zone. The same flood zone might be crossed by the corridor and its variations at different locations. In such cases, the feature will be marked “Avoided” for the corridor, but will appear again for the variations.

Table 6-39. Hydrographic areas along Carlin Corridor and its variations.[a]

Corridor description	Hydrographic areas	Designated Groundwater Basins	
		Number	Percent of corridor length
Carlin Corridor	12	6	70
with Monitor Valley Option	12	5	50
with Goldfield Alternate	11	5	70
other alternates[a]	12	6	70

a. Crescent Valley, Wood Spring, Rye Patch, Steiner Creek, Mud Lake, Bonnie Claire, Oasis Valley, and Beatty Wash.

The withdrawal of about 12,000 cubic meters (10 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 67 wells along the corridor would mean that many hydrographic areas would have multiple wells. As indicated in Table 6-39, about 70 percent of the length of the Carlin Corridor is in Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. With such a large portion of the corridor over these basins, however, this would mean that DOE would truck water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation would ensure no adverse effects to groundwater resources. Use of the Monitor Valley Option would decrease the portion of the corridor crossing Designated Groundwater Basins and possibly increase DOE's flexibility in obtaining water along the corridor.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Carlin Corridor would require about 43,000 tanker-truck loads of water or about 9 truckloads each day for each work camp along the corridor. Again, water obtained from permitted sources, which would be within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.2.3 Carlin Rail Biological Resources and Soils

Construction. The construction of a rail line in the Carlin Corridor, including its variations, would disturb approximately 19 square kilometers (4,700 acres) (Table 6-35). Areas in nine of the land-cover types identified in Nevada (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5) would be affected by the construction of a branch rail line in the Carlin Corridor (Table 6-40). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. The EIS analysis assumed that the composition of land-cover types in these areas would be similar to the cover types in the corridor. The greatest amounts of disturbance would occur in the sagebrush, salt-desert scrub, and creosote bursage land-cover types for both the Big Smoky Valley Option and Monitor Valley Option, but would involve far less than 0.01 percent of the existing area in those land-cover types. The fraction disturbed for each cover type would be very small. The disturbance would have no discernible impact on the availability of habitat for plants or animals associated with any cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to that in the unvaried corridor.

About 50 kilometers (31 miles) of its length along the southern end of the corridor occurs in desert tortoise habitat. Assuming 0.06 square kilometer (15 acres) disturbed per linear kilometer of railroad, construction activities would disturb about 3 square kilometers (740 acres) of this habitat. Such activities could kill individual desert tortoises; however, the abundance of this species is low in this area (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few. Relocation of tortoises along the corridor prior to construction would minimize losses of individuals. The presence of a branch rail line could interfere with movement of individual tortoises. If DOE selected this corridor, it would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) regarding this species, and would implement all terms and conditions required by the Fish and Wildlife Service.

Table 6-40. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Carlin Corridor.[b,c]

	Big Smoky Valley Option		Monitor Valley Option			
Land-cover type	Percent of corridor length	Land area	Percent of corridor length	Land area	Area in Nevada	Percent disturbed
Agriculture	0	0	0	0	5,200	0
Blackbrush	0.1	0.02	0.1	0.02	9,900	<0.001
Creosote-bursage	5.9	1.1	5.9	1.2	15,000	0.007
Grassland	0	0	0	0	2,800	0
Greasewood	6.4	1.2	4.3	0.86	9,500	0.013
Hopsage	1.9	0.37	1.9	0.38	630	0.057
Juniper	0	0	0	0	1,400	0
Mojave mixed scrub	4.5	0.87	4.5	0.9	5,600	0.015
Pinyon-juniper	0.6	0.12	0.6	0.12	15,000	<0.001
Playa	0	0	0	0	7,000	0
Sagebrush	24.9	4.8	43.1	8.7	67,000	0.012
Sagebrush/grassland	2.3	0.44	5.9	1.2	52,000	0.002
Salt desert scrub	53.4	10	33.7	6.8	58,000	0.018
Urban	ND[d]	ND	ND	ND	2,400	ND
Total[e]	100	19.3	100	20.1	250,000	N/A[f]

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.
e. Totals might differ from sums of values due to rounding.
f. N/A = not applicable.

Three other sensitive species occur in the 400-meter- (0.25-mile)-wide corridor: one population of a sensitive plant species, the Nevada sanddune beardtongue; and one population each of two sensitive animal species (a ferruginous hawk nesting area and the San Antonio pocket gopher). Use of the Monitor Valley Option rather than the Big Smoky Valley Option would avoid the pocket gopher population, and the Steiner Creek Alternate would avoid the hawk nesting area (Appendix J, Section J.3.1.2 lists corridor variations). These populations could be disturbed during construction activities. Adverse impacts to the hawk nesting area could be long term because periodic disturbances associated with the presence of a railroad could cause the hawks to abandon the area.

At least three populations of three sensitive plant species occur outside the corridor, but within 5 kilometers (3 miles). Use of the Monitor Valley Option would avoid one of these populations. DOE anticipates no impacts to these populations because land disturbance would not extend to these areas and changes in the aquatic or soil environment in these areas as a result of construction or long-term presence of a railroad would be unlikely.

Fourteen populations of eight sensitive animal species occur outside the corridor, but within 5 kilometers (3 miles). Ten populations of five of these species are associated with springs or aquatic habitat. These populations would not be affected by construction activities due to their distance from the corridor. The Monitor Valley Option would avoid one population each of two of these species.

This rail corridor, including its variations, crosses seven areas designated as game habitat and six areas designated as wild horse and burro management areas (see Chapter 3, Section 3.2.2.1.4). Construction activities would reduce habitat in these areas. Wild horses, burros, and game animals near these areas during construction would be disturbed, and their migration routes could be disrupted. In addition, there are 17 areas designated as game habitat outside the 400-meter (0.25-mile)-wide corridor but within 5 kilometers (3 miles). Larger game animals occupy large home ranges and could easily traverse the distance between the designated habitat and the proposed corridor. Four of these areas are associated with sage grouse (1 nesting and 3 strutting) and probably would not be affected by construction of the rail line.

One group of springs and three to four stream or riparian areas are within the 400-meter (0.25-mile)-wide corridor, and its variations (Table 6-37). Although no formal delineations have been made, these areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. In addition, the corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. DOE anticipates some changes to local drainage along a branch rail line and would design the rail line to accommodate existing drainage patterns.

In addition, as many as 60 known springs and 6 riparian areas occur outside the corridor, but within 5 kilometers (3 miles), including the corridor variations. Nine known populations of four sensitive animal species are associated with these aquatic resources. DOE anticipates no impacts to these populations because these areas would not be disturbed during construction or by the long-term presence of a railroad. Although there are differences in the number of springs or riparian areas that some corridor variations would avoid, the Monitor Valley Option would avoid 13 of the springs and four of the riparian areas that are outside of the corridor but within 5 kilometers.

Construction activities would temporarily disturb about 19 square kilometers (4,700 acres) of soils in and adjacent to the corridor. The impacts to soils of disturbing 19 square kilometers (4,700 acres) along the 520-kilometer (323-mile)-long corridor would be transitory and small. However, several soil characteristics could influence construction activities and the amount of disturbed area. Soils susceptible to water or wind erosion occur along much of the corridor and its variations as do soils exhibiting relatively high shrink-swell characteristics (see Chapter 3, Section 3.2.2.1.4). Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by wind. Erosion control during construction, and revegetation or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is, high) shrink-swell characteristics could influence the amount of area disturbed by construction if soils from outside areas had to be brought in for replacement or mixing with native soil.

As stated in Chapter 3, Section 3.2.2.1.4, potential variations identified for the Carlin Corridor could avoid some biological resources, as listed in Table 6-41.

6.3.2.2.2.4 Carlin Rail Cultural Resources

Construction. This section discusses the segment of the Carlin Corridor from the existing Union Pacific main line railroad near Beowawe in north-central Nevada to its junction with the Caliente Corridor, northwest of Mud Lake. The remainder of the corridor is the same as the final segment of the Caliente Corridor from that point to the proposed repository; impact potential along that segment is discussed in Section 6.3.2.2.1.4.

Archaeological site file searches for the overall Carlin Corridor, including its variations (see Appendix J, Section J.3.1.2), resulted in the identification of 110 known sites (see Chapter 3, Section 3.2.2.1.5), 47 of which are eligible or potentially eligible for inclusion in the *National Register of Historic Places*. The segment of the Carlin Corridor north of the junction point with the Caliente Corridor crosses or passes through several potentially important areas for archaeological and historical sites. Based on currently available information (DIRS 155826-Nickens and Hartwell 2001, p. 27), each of the valleys through which the corridor and its variations pass—Crescent, Grass, Big Smoky, Monitor, and Ralston—have medium to high potential for prehistoric and historic Native American sites. Late 19th- and early 20th-century Western Shoshone village sites are collocated with the historic Grass Valley Ranch; similar situations might occur at other historic ranches the Corridor passes.

Table 6-41. Biological resources avoided by Carlin Corridor variations.[a]

	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
Alignment variation resource	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Steiner Creek Variation				
Sensitive species–ferruginous hawk nesting	1	2	1	0
Game habitat–sage grouse strutting	2	3	1	1
Springs or groups of springs	4	59	0	2
Riparian areas	3	7	2	1
Rye Patch Variation				
Springs or groups of springs	4	59	1	0
Riparian areas	3	7	1	0
Monitor Valley Variation				
Sensitive species				
Big Smoky Valley speckled dace	0	1	0	1
Crescent Dune aegialian scarab	0	1	0	1
Nevada sanddune beardtongue	1	1	0	1
San Antonio pocket gopher	1	0	1	0
Game habitat				
Pronghorn–year round	1	0	1	0
Waterfowl	0	1	0	1
Springs or groups of springs	4	59	0	13
Riparian areas	3	7	0	4

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.

Between Beowawe and U.S. Highway 50, the Carlin Corridor intersects with the California Emigrant Trail and the Pony Express Trail, both designated by Congress as *National Historic Trails* under the National Trails System Act, and the historic Pacific Telegraph Line, Butterfield Overland Mail and Stage route, and Lincoln Highway routes (DIRS 155826-Nickens and Hartwell 2001, p. 15). None of these resources has been evaluated for eligibility for the *National Register of Historic Places*, although the segment of the Pony Express Trail intersected by the Carlin Corridor, Rye Patch Alternate, and Monitor Valley Option has been designated a High Potential segment by the National Park Service. The Monitor Valley Option passes within view of the Belmont Historic District at the southern end of the valley, and to the south in Ralston Valley passes close to known but unrecorded and unevaluated archaeological sites, as well as the former bombing range for the Tonopah Army Air Station.

Construction of a branch rail line in this corridor could affect two historic Native American cemeteries, one in Crescent Valley and the other in Grass Valley (DIRS 155826-Nickens and Hartwell 2001, p. 27). The corridor passes within 3 kilometers (2 miles) of another cemetery southeast of Beowawe that local Western Shoshone families still use. Crescent Valley itself is part of the disputed Western Shoshone homelands, and grazing rights throughout the valley have been the subject of litigation between local Western Shoshone ranchers and the Bureau of Land Management.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.2.5 Carlin Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Carlin branch rail line would be small (see Table 6-42). The analysis evaluated the potential for impacts in terms of

Table 6-42. Impacts to workers from industrial hazards during rail construction and operations for the Carlin Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	99	95
Lost workday cases	49	52
Fatalities	0.14	0.26
Noninvolved workers		
Total recordable cases	5.9	5.4
Lost workday cases	2.2	2.0
Fatalities	0.006	0.006
Totals[d]		
Total recordable cases	110	100
Lost workday cases	51	54
Fatalities	0.14	0.27

a. Totals for 46 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities.

The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-43 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Carlin Corridor. Table 6-44 lists the incident-free impacts, which would include transportation along the Carlin Corridor and transportation along railways in Nevada that led to a Carlin branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that would not have the capability to load rail casks while operational.

Table 6-43. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Carlin Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	19,000,000	0.3	0.04
Commuting workers	76,000,000	0.8	0.10
Subtotals	*95,000,000*	*1.1*	*0.14*
Operations[c]			
Commuting workers	68,000,000	0.7	0.09
Totals	*160,000,000*	*1.8*	*0.23*

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 46 months for construction.
c. Totals for 24 years for operations.

Table 6-44. Health impacts from incident-free Nevada transportation for the Carlin Corridor.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	940	980
Estimated latent cancer fatalities	0.02	0.38	0.39
Public			
Collective dose (person-rem)	7	32	38
Estimated latent cancer fatalities	0.003	0.02	0.02
Estimated vehicle emission-related fatalities	0.002	0.017	0.018

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

6.3.2.2.2.6 Carlin Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction of a branch rail line in the Carlin Corridor and with the operation of the line.

The Carlin Corridor passes through Lander County, very small portions of Eureka and Esmeralda Counties, and Nye County. DOE considered potential socioeconomic impacts in Lander, Eureka, and Esmeralda Counties collectively as part of the Rest of Nevada, the portion of the State outside the region of influence.

Construction. The length of the Carlin Corridor, 520 kilometers (323 miles), would determine the number of workers required. The construction of a branch rail line in this corridor would require workers laboring for 2.5 million hours or 1,230 worker-years during the 46-month construction period (DIRS 154822-CRWMS M&O 1998, all). During the work week, the workers would commute to and temporarily live in five construction camps.

Employment

DOE anticipates that total (direct and indirect) employment in Nevada attributable to the construction of a Carlin branch rail line would peak in the first year of construction, 2006, at about 783 jobs, 85 percent of which would be in the region of influence. The increase in employment represents less than 1 percent of the baseline for employment in each of the three counties in the region of influence (Clark, Nye, and Lincoln Counties) and in the Rest of Nevada. Clark County would supply about 574 workers, Nye County 95, and Lincoln County 1. The balance of the workers, 113, would come from the Rest of Nevada. Employment of Carlin Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth of 19,915 jobs (2009 to 2010) in the State of Nevada would be reduced by approximately 700. The expected 14,886 additional jobs in Clark County would be reduced by 690, and the expected growth of 330 jobs in Nye County would be reduced by 46. The expected growth of 24 jobs in Lincoln County would be unaffected. The expected 4,675 additional jobs in the Nevada counties outside the region of influence would be supplemented by 37. DOE anticipates that project-related workers not moving to Carlin Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in Nevada attributable to the construction of a Carlin rail line, which would lag increases in employment, would peak 2 years later in 2009 at about 728 persons. About 683 persons, or 94 percent of the expected additional residents, would live in the region of influence. Clark County would gain about 625 residents, Nye County would gain about 57 residents, and Lincoln County would gain 1. The Rest of Nevada, would gain approximately 44 residents. Because Clark County has a larger population, the expected impact from the change in population would be less than 1 percent. The impacts of projected increases in population in Nye and Lincoln Counties, and in the Rest of Nevada would also be less than 1 percent. Because the increases in population resulting from the construction of a rail line in the Carlin Corridor would be small and transient in Clark, Nye, and Lincoln Counties, and in the Rest of Nevada, impacts to schools or housing would be unlikely.

Economic Measures

The expected peak annual changes in economic measures in the State due to the construction of a branch rail line in the Carlin Corridor would be increases of $21.4 million in real disposable income in 2009; $36.0 million in Gross Regional Product during 2007; and $2.5 million in State and local expenditures in 2009 with 90 percent concentrated in the region of influence. More than 90 percent of the increase in Gross Regional Product and real disposable income would be generated in Clark County. Clark County would absorb approximately 83 percent of the increases in State and local government expenditures. About 3 percent of the increase in Gross Regional Product and real disposable income would be generated in Nye County as would 7 percent of the expenditures by State and local governments. Because there would be virtually no change to employment or population in Lincoln County attributable to a rail line in the Carlin Corridor, there would be virtually no impact or change to Gross Regional

Product, real disposable income, or expenditures by State and local government. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Construction-related impacts to employment, population, real disposable income, Gross Regional Product, and State and local government expenditures for a branch rail line in the Carlin Corridor would be less than 1 percent of the applicable baselines for Clark, Nye, and Lincoln Counties and the Rest of Nevada.

Transition and Operations Period. In the period from 2010 to 2012, the State of Nevada would have an average of 27 fewer jobs. For perspective, the State of Nevada would have an average employment of about 1.5 million during this same period. Slightly slower growth would be confined to Clark County from 2010 to 2016. Growth in employment in Clark County during this transitional period would be approximately 66 fewer jobs than if DOE did not build a branch rail line in the Carlin Corridor. The Lincoln County employment baseline during this period would average about 75,000 jobs. During this period, Nye County would gain 5 jobs. There would be no change in employment in Lincoln County. A Carlin branch rail line would accelerate the rate of growth in the region's employment starting in 2016. The area outside the region of influence, the Rest of Nevada, would gain approximately 78 project-related jobs during this transition period. A Carlin rail line would contribute to growth in residential populations in and outside the region of influence throughout the transition period and to the employment base in the State after 2012.

Employment and Population

Estimated direct employment for operations in the Carlin Corridor would be 47 workers during the 24 years of operations. The change in total employment would average about 86 jobs in Nevada. DOE assumed that 6 of the additional workers would be employed in Clark County, about 6 in Nye County, and none in Lincoln County. The rest of the individuals would work in the Rest of Nevada, primarily in Elko County. The average annual addition to population in the State attributable to a branch rail line in the Carlin Corridor would be about 294 persons. About 160 of these persons would live in Clark County, 31 in Nye County, and none in Lincoln County. The rest of the individuals would live elsewhere within the State. DOE assumed that half of the Carlin rail operational personnel (approximately 24 directly employed individuals) would live at each end of the branch rail line. Rail operations employees and indirectly employed individuals who would live near the Beowawe end of the rail line would live in or near the Town of Elko in Elko County. Impacts due to changes in population and employment attributable to a Carlin rail line in Elko County, which had an estimated 2000 population of about 45,500 and about 21,100 jobs, would be less than 0.5 percent. Because impacts from increases in population and employment in each county would be small, impacts to schools or housing would be unlikely. The average annual impact, in relation to the baselines for population and employment in Clark, Nye, and Lincoln Counties and the Rest of Nevada, would be less than 1 percent.

Economic Measures

From 2010 until 2033 the estimated average annual increase in Nevada from operating a branch rail line in the Carlin Corridor in real disposable income would be $5.7 million. Approximately 33 percent would be generated in the region of influence, and the balance would be generated primarily in Elko County. The average increase in annual Gross Regional Product in the State attributable to a Carlin rail line would be about $5.3 million, of which $4.9 million would come from goods and services outside the region of influence. On average, during operation of a Carlin rail line, changes in real disposable income would exceed changes in Gross Regional Product. The increase in annual State and local government expenditures would be about $1.2 million, much lower than those reported above for construction. Approximately 46 percent of these additional expenditures would come from outside the region of influence. The impact of changes in Gross Regional Product, real disposable income, and expenditures by State and local governments would be less then 1 percent for Clark, Nye, and Lincoln Counties and for the Rest of Nevada.

DOE performed a detailed analysis for the Carlin rail line because of its length. The results of this analysis are representative of the potential variations (options and alternates) listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar to those listed in Table 6-36.

6.3.2.2.2.7 Carlin Rail Noise and Vibration

Over most of its length, the Carlin Corridor, including the Monitor Valley and Big Smoky Valley Options, passes through undeveloped land managed by the Bureau of Land Management. Human inhabitants of this land consist primarily of isolated ranchers and persons involved with outdoor recreation. DOE identified 12 communities along or near the Carlin Corridor (including its Monitor Valley and Big Smoky Valley Options) and estimated the distances from a branch rail line to the community's nearest boundary (Table 6-45). The estimated maximum railroad noise from a two-locomotive train would occur at the boundary of the community. Estimated noise levels would not exceed the 60-dBA benchmark for residential communities during daytime hours. Communities within 1 kilometer (0.6 mile) of the rail line would experience single episodes of noise higher than the nighttime 50-dBA benchmark. A limitation of 10 dBA above the benchmark is allowable if its duration is less than 5 minutes in an hour (Washington Administrative Code-170-60). The estimated duration of noise that peaked at 57 dBA would be less than 2 minutes in communities 1 kilometer from the rail line at a speed of 50 kilometers (30 miles) per hour. For distances of 5 kilometers (3 miles) or greater, the estimate of 26 dBA would be subject to large uncertainty.

Table 6-45. Estimated propagation of noise (dBA) from the operation of a waste transport train with two locomotives in communities near the Carlin Corridor.

Corridor/community	Distance (kilometers)[a]	Estimated noise (dBA)[b]
Carlin Corridor		
Beowawe	3.2[c]	32
Crescent Valley	1.9	44
Austin	16	< 26
Big Smoky Valley Option		
Carver	1.0	57
Round Mountain	1.0	57
Manhattan	1.0	57
Monitor Valley Option		
Belmont	2.0	43
Tonopah (east alignment)	8[c]	< 26[d]
Tonopah (west alignment)	13[c]	< 26
Goldfield	6.0	< 26
Beatty	9.6[c]	< 26
Amargosa Valley	9.6[c]	< 26

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
c. Noise estimates at distances greater than 2.0 kilometers (1.2 miles) have large uncertainty.
d. At these distances, the A-weighted sound pressure level is dominated by lower frequencies (lower than 63 Hertz) and would not be distinguishable from normal background levels of noise.

In addition to passing near communities, the variations of the Carlin Corridor pass through areas with farms and ranches. Therefore, some rural residences could fall in the region of influence for noise. The corridor and its 10 variations (see Appendix J, Section J.3.1.2) are at least 1 kilometer (0.6 mile) or more from every town along its length. The noise from trains would not exceed daytime noise standards for residential areas (60 dBA) more than 1 kilometer from a branch rail line. Because a Carlin rail line would pass near some communities, there would be a potential for noise impacts from both construction and operations. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passed near a community, train speeds could be limited to the extent necessary to ensure that noise was below levels listed in accepted noise standards.

The Carlin Corridor passes within 1.9 kilometers (1.2 miles) of the border of the Timbisha Shoshone Trust Lands parcel. The Bonnie Claire Alternate of the corridor passes through 4.1 kilometers (2.5 miles) of the Timbisha Shoshone Trust Lands parcel near the intersection of State Route 267 and U.S. Highway 95. Noise levels from trains passing through the parcel would be at 90 dBA at 15 meters (49 feet) for the Bonnie Claire Alternate. At the closest point of the Carlin Corridor, the estimated noise levels would be 44 dBA.

The estimated population residing within 2 kilometers (1.25 miles) of the Carlin Corridor in 2035 would be about 3,200 persons. The potential for human annoyance would be small.

Vibration. There are no known ruins of cultural significance along the Carlin Corridor. A branch rail line in the corridor or its variations would be distant from historic structures and buildings, so vibration impacts to such structures would be unlikely. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.2.8 Carlin Rail Utilities, Energy, and Materials

Table 6-46 lists the projected use of fossil fuels and other materials in the construction of a Carlin branch rail line.

Table 6-46. Construction utilities, energy, and materials for a Carlin branch rail line.

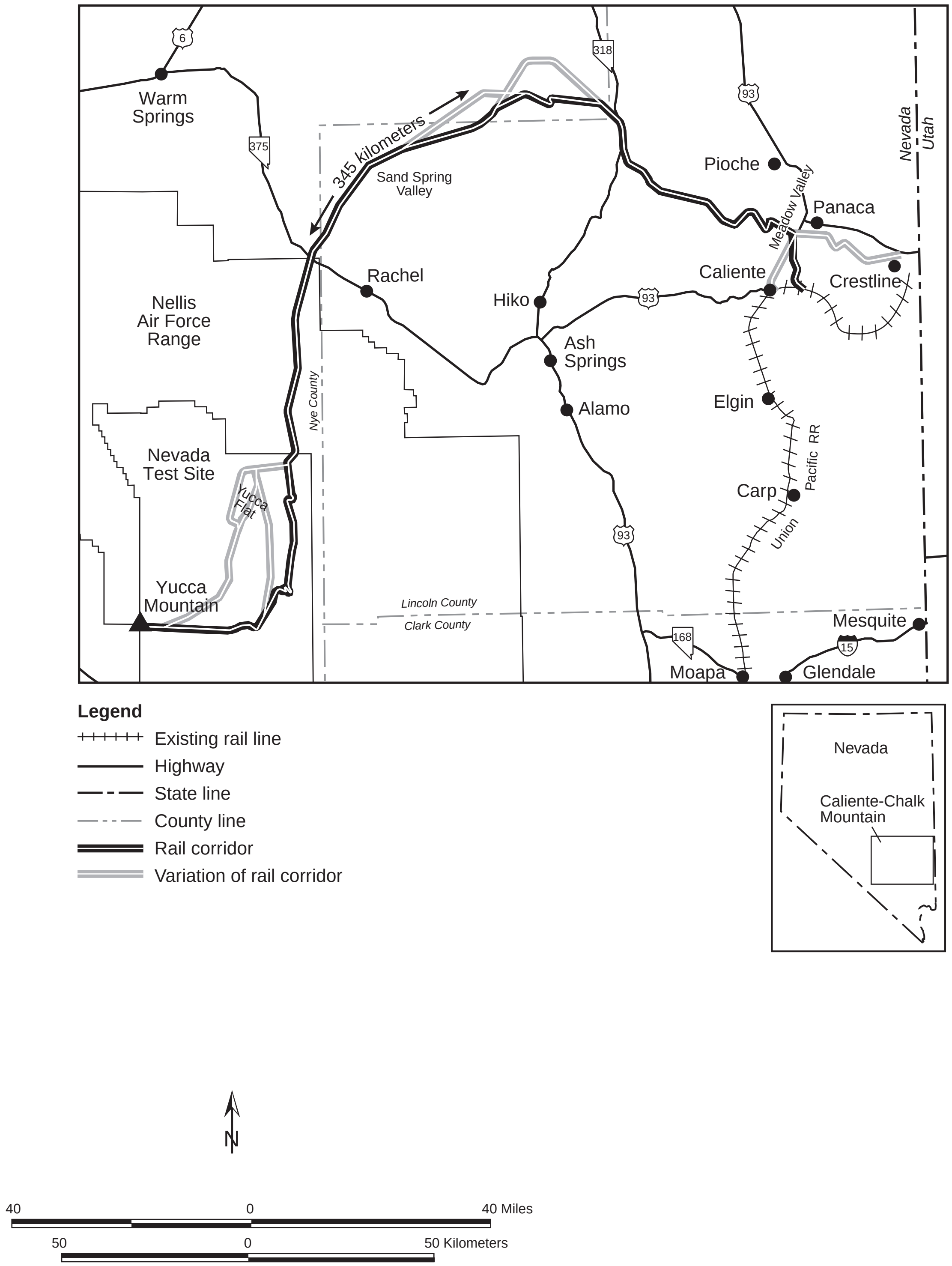
Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
510 - 540	39 - 41	790 - 840	71 - 75	400 - 420

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.3 *Caliente-Chalk Mountain Rail Corridor Implementing Alternative*

The Caliente-Chalk Mountain Corridor is identical to the Caliente Corridor until it reaches the northern boundary of the Nellis Air Force Range. At this point the Caliente-Chalk Mountain Corridor turns south through the Nellis Air Force Range and the Nevada Test Site to the Yucca Mountain site. Figure 6-17 shows this corridor along with possible variations identified by engineering studies (DIRS 154822-CRWMS M&O 1998, all). The corridor variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-17. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible corridor variations. The corridor is 345 kilometers (214 miles) long from its link at the Union Pacific railroad near Caliente to Yucca Mountain. Variations of the route range from 340 to 380 kilometers (210 to 240 miles).

The construction of a branch rail line in the corridor would require approximately 43 months. Construction would take place simultaneously at a number of locations. An estimated four construction camps would be established at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities. A train would take about 8 hours to travel from the junction with the Union Pacific mainline to a Yucca Mountain Repository on a Caliente-Chalk Mountain branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Line Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Caliente-Chalk Mountain Corridor would be $622 million in 2001 dollars.



To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104560-YMP (1998, all).

Figure 6-17. Caliente-Chalk Mountain Corridor.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to air quality, aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.3.1 Caliente-Chalk Mountain Rail Land Use and Ownership

Construction. Table 6-47 summarizes the amount of land required for the Caliente-Chalk Mountain corridor, its ownership, and the estimated amount of land that would be disturbed. Table 6-48 summarizes the amount of land required for the Caliente-Chalk Mountain corridor variations and its ownership.

Table 6-47. Land use in the Caliente-Chalk Mountain Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	345	344 - 382
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	138 (100)	138 - 153
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	78 (56)[e]	77.4 - 88.5
Air Force	21.5 (16)	21.5 - 21.5
DOE	37.8 (27)	31.5 - 37.8
Private	0.8 (0.6)	0.8 - 1.1
Other	None	None
Land area in 60-meter[f] *right-of-way (square kilometers)*	20.7	20.6 - 22.9
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	9.6	9.6 - 10.6
Outside 60-meter right-of-way	3	3 - 3.4

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. Percentages do not total 100 due to rounding.
f. 60 meters = 200 feet.

The Caliente-Chalk Mountain Corridor would involve several road, power line, and utility rights-of-way before it entered the Nellis Air Force Range west of Groom Mountain and then the Nevada Test Site. The rights-of-way are similar to those discussed in relation to the Caliente Corridor and therefore the land-use impacts for this section of the corridor would be similar (see Sections 6.3.2.1 and 6.3.2.2.1). South of Rachel, Nevada the corridor crosses an additional road right-of-way (DIRS 104993-CRWMS M&O 1999, Table 5, p. 18). Variations of the corridor, as indicated in Appendix J, Section J.3.1.2, provide flexibility to address engineering, land use, or environmental constraints. Included are variations identified to provide flexibility to circumvent Test Site surface areas and associated facilities and radiologically contaminated areas. The corridor would also cross five oil and gas leases and three grazing allotments (Highland Peak, Bennett Springs, and Black Canyon). Many of the impacts along the Caliente-Chalk Mountain Corridor would be similar to those described for the Caliente Corridor (see Section 6.3.2.2.1) or are common to all five rail corridors as discussed in Section 6.3.2.1. The following paragraphs discuss impacts unique to the Caliente-Chalk Mountain Corridor.

Table 6-48. Possible variations in the Caliente-Chalk Mountain Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Land ownership [square kilometers (percent)] Bureau of Land Management	Private	DOE
Eccles Option	16.7	6.7	6.3 (95)	0.4 (5)	--[e]
Caliente Option	17.2	6.9	6.21 (90)	0.69 (10)	--
Crestline Option	37.8	15.1	14.5 (95.9)	0.6 (4.1)	--
White River Alternate	47.5	19	18.98 (99.9)	0.02 (<0.1)	--
Garden Valley Alternate	37.7	15.1	15.1 (100)	--	--
Orange Blossom Road Option	85.9	34.4	--	--	34.4 (100)
Topopah Option	78.4	31.4	--	--	31.4 (100)
Topopah Option with Mine Mountain Alternate	77.8	31.1	--	--	31.1 (100)
Topopah Option with Area 4	72.1	28.8	--	--	28.8 (100)
Mercury Highway Option	52.3	20.9	--	--	20.9 (100)

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. NA = not applicable; the Eccles Option and Orange Blossom Road Option lengths are included in the overall corridor length.
e. -- = none.

The Caliente-Chalk Mountain Corridor passes just east of the Weepah Springs Wilderness Study Area and just north of the Worthington Mountains Wilderness Study Area. The corridor involves land controlled by the Nellis Air Force Range (also known as the Nevada Test and Training Range) and, according to the Air Force, would affect Range operations. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range before DOE could build and operate this line.

Operations. DOE expects operations along the Caliente-Chalk Mountain Corridor to cause smaller impacts than the construction phase of the project.

The Air Force has identified national security issues related to a Chalk Mountain route (DIRS 104887-Henderson 1997, all), citing interference with Nellis Air Force Range testing and training activities. In response to Air Force concerns, DOE regards the route as a “non-preferred alternative.”

6.3.2.2.3.2 Caliente-Chalk Mountain Rail Hydrology

Surface Water

Chapter 3, Section 3.2.2.1.3, discusses surface-water resources along the Caliente-Chalk Mountain Corridor; Table 6-49 summarizes these resources. The use of corridor variations could result in changes to the number of surface-water resources in the vicinity of the corridor. However, the changes would be primarily to the number of resources outside, but within 1 kilometer (0.6 mile), of the corridor. As discussed in Section 6.3.2.1, impacts during construction or operations from the possible spread of construction-related materials by precipitation or intermittent runoff events, releases to surface waters, and the alteration of natural drainage patterns or runoff rates that could affect downgradient resources would be unlikely.

Table 6-50 lists flood zones identified along the Caliente-Chalk Mountain Corridor and its variations. This corridor would cross at least three 100-year flood zones or flood-zone groups before entering the Nellis Air Force Range. Two of the four variations would change the number of flood zones crossed by one (up or down). The low number of flood zones identified for the Caliente-Chalk Mountain Corridor must be qualified by the fact that the Federal Emergency Management Agency maps, from which DOE

Table 6-49. Surface-water resources along Caliente-Chalk Mountain Corridor and its variations.[a,b,c]

	Resources in 400-meter[d] corridor			Resources outside corridor within 1 kilometer[e]		
Corridor description	Spring	Stream/ riparian area	Reservoir	Spring	Stream/ riparian area	Reservoir
Caliente-Chalk Mountain Corridor	--[f]	2	--	5	--	--
with Crestline Option	--	2	--	7	--	--
with Caliente Option	1	2	--	7	--	--
with Topopah Option	--	2	--	4	--	--
with Topopah-Area 4 Alternate	--	2	--	3	--	--
with Topopah-Mine Mountain Alternate	--	2	--	4	--	--

a. Source: Reduced from table in Chapter 3, Section 3.2.2.1.3.
b. Resources are the number of locations; that is, DOE counted a general location with more than one spring as one water resource.
c. Resources listed for variations are for the entire corridor with only the identified variations changed. Variations not listed (White River Alternate, Garden Valley Alternate, Mercury Highway Connection, Orange Blossom Road Option) are not associated with identified water resources, nor would they avoid resources along the corridor.
d. 400 meters = about 0.25 mile.
e. 1 kilometer = about 0.6 mile.
f. -- = none.

derived the flood zone information, provided coverage for only about 10 percent of the corridor length. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Caliente-Chalk Mountain Corridor passes).

The estimated amount of water needed for construction of a branch rail line in the corridor for soil compaction, dust control, and workforce use would be about 594,000 cubic meters (480 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 43 wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 14,000 cubic meters (11 acre-feet). DOE would use most (90 percent) of the water for compaction of fill material, and the estimate of fill quantities needed for construction would vary if the Department used variations. Use of either the Topopah or Mercury Highway Options on the Nevada Test Site would involve the largest increase in fill material and could increase the total water needed for this corridor by as much as 16 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and if the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-51 summarizes the status of the hydrographic areas associated with the Caliente-Chalk Mountain Corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins. Use of the variations (Caliente Option, Crestline Option, White River Alternate, Garden Valley Alternate, Mercury Highway Option, Topopah Option, Mine Mountain Alternate, Orange Blossom Road Option, and Area 4 Alternate) would change the number of hydrographic areas crossed, but would have no effect on the portion of the corridor crossing Designated Groundwater Basins.

Table 6-50. 100-year flood zones crossed by the Caliente-Chalk Mountain Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (yes or no)
Eccles Siding to Meadow Valley	0.2[e]	Clover Creek (intermittent)	Y-1
	0.8[e]	Meadow Valley Wash (wet)	Y-1,2
Meadow Valley Wash to Sand Spring Valley	0.5[e]	White River (intermittent)	N
Sand Spring Valley to Yucca Mountain	--[f,g]	Not available	
Variations			
1. Crestline Option	0.8	Crosses Meadow Valley Wash (wet)	
2. Caliente Option	0.8	Crosses Meadow Valley Wash (wet)	
	0.2	Crosses Clover Creek (intermittent)	
	0.9	Crosses Meadow Valley Wash (wet) three times, rail corridor runs adjacent to Meadow Valley Wash. Passes in and out of flood zone	
3. White River Alternate	None	Located to the north of the corridor	
4. Garden Valley Alternate	None	Located to the north of the corridor	
5. Topopah Option	--[g]	Located adjacent to corridor	
5a. Area 4 Alternate	--[g]	Variation along the Topopah Option	
5b. Mine Mountain Alternate	--[g]	Variation along the Topopah Option	
6. Mercury Highway Option	--[g]	Located adjacent to corridor	

a. Areas where natural floodwater movement might be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Lincoln and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).
b. About 91 percent of the Caliente-Chalk Mountain Corridor is not available on Federal Emergency Management Agency maps, due primarily to limited coverage in Lincoln County, the Nellis Air Force Range, and the Nevada Test Site.
c. To convert kilometers to miles, multiply by 0.62137.
d. Certain 100-year flood zones can be avoided by corridor variations. These are identified with a "Y" (yes) and a number representing the specific variation(s) that avoid the specific flood zone. The same flood zone might be crossed by both the corridor and variations at different locations. In such cases, the feature will be marked "Avoided" for the corridor route, but will appear again for the variations.
e. Projected from limited data. Specific area not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.
f. No information available on Federal Emergency Management Agency maps.
g. Limited information due to the Nellis Air Force Range or the Nevada Test Site.

Table 6-51. Hydrographic areas along Caliente-Chalk Mountain Corridor and its variations.

		Designated Groundwater Basins	
Description	Hydrographic areas	Number	Percent of corridor length
Caliente-Chalk Mountain Corridor	11	2	30
Variations[a]	10 to 12	2	30

a. Several of the variations would involve small changes in the hydrographic areas crossed or the crossing distances. However, all (Caliente Option, Crestline Option, White River Alternate, Garden Valley Alternate, Mercury Highway Option, Topopah Option, Mine Mountain Alternate, Orange Blossom Road Option, and Area 4 Alternate) would cross the same two Designated Groundwater Basins. Rounded to the nearest 10 percent, this would represent the same portion of the total corridor.

The withdrawal of about 14,000 cubic meters (11 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 43 wells along the corridor would mean that many hydrographic areas would have multiple wells. As listed in Table 6-51, about 30 percent of the corridor length is over

Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use well locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources did not receive adverse impacts.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Caliente-Chalk Mountain Corridor would require about 32,000 tanker-truck loads of water or about eight truckloads each day for each work camp area along the corridor. Again, water obtained from permitted sources, which would provide water in allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.3.3 Caliente-Chalk Mountain Rail Biological Resources and Soils

Construction. The construction of a branch rail line in the Caliente-Chalk Mountain Corridor, including potential variations, would disturb about 12 square kilometers (3,000 acres) of land (Table 6-47). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Areas in eight of the land-cover types identified in Nevada (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5) would be affected (Table 6-52). The greatest amounts of disturbance would occur in the salt desert scrub, sagebrush, and blackbrush land cover types, but would involve far less than 0.01 percent of the existing area in those types. The fraction disturbed for each cover type would be very small. The disturbance would have no discernable impact on the availability of habitat for plants or animals associated with any cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to the unvaried corridor.

About 40 kilometers (25 miles) of the corridor length at its southern end, including potential variations, crosses desert tortoise habitat. Assuming that 0.06 square kilometer (15 acres) would be disturbed for each linear kilometer of railroad, construction activities would disturb as much as 2.4 square kilometers (590 acres) of desert tortoise habitat, some of which is classified as critical habitat. Such activities could kill individual desert tortoises; however, their abundance is low in this area (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few. The presence of a branch rail line could interfere with movements of individual tortoises. Relocation of tortoises along the corridor prior to construction would minimize losses of individuals. If DOE selected this corridor, it would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) in relation to this species and would implement all terms and conditions required by the Fish and Wildlife Service.

Although the southwestern willow flycatcher occurs near some portions of the Caliente-Chalk Mountain Corridor, there is no suitable habitat of dense riparian vegetation for this listed endangered species in the corridor (DIRS 152511-Brocoum 2000, pp. A-9 to A-13).

The Eccles, Crestline, and Caliente variations for this corridor cross a portion of the Meadow Valley Wash, which is habitat for an unnamed subspecies of the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker, both of which are sensitive species (see Chapter 3, Section 3.2.2.1.4). The construction of a branch rail line near Caliente could temporarily affect populations of these fish by increasing the sediment load in the wash during construction. Three special status plant

Table 6-52. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Caliente-Chalk Mountain Corridor.[b,c]

Land cover type	Percent of corridor length	Area disturbed	Area in Nevada	Percent disturbed
Agriculture	0.5	0.05	5,200	0.01
Blackbrush	24.8	2.45	9,900	0.02
Creosote-bursage	0.0	0	15,000	0
Grassland	0.4	0.04	2,800	0.001
Greasewood	0.0	0	9,500	0
Hopsage	1.9	0.19	630	0.03
Juniper	0.0	0	1,400	0
Mojave mixed scrub	2.4	0.24	5,600	0.004
Pinyon-juniper	0.0	0	14,700	0
Playa	0.0	0	7,000	0
Sagebrush	30.1	3	67,000	0.004
Sagebrush/grassland	0.4	0.04	52,000	<0.001
Salt desert scrub	39.3	3.89	58,000	0.007
Urban		ND[d]	2,400	ND

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.

species are found along this corridor and its variations but could be avoided during land-clearing activities and would not be affected.

At least 40 populations of five sensitive plant species occur outside the 400-meter (0.25-mile)-wide corridor, but within 5 kilometers (3 miles) of the corridor. Several other populations of three other sensitive plant species occur within 5 kilometers of one or more of the corridor variations listed in Appendix J, Section J.3.1.2. DOE anticipates that these populations would be unaffected because land disturbance would not extend to these areas and changes in the aquatic or soil environment in these areas as a result of construction or the long-term presence of a railroad would be unlikely.

This rail corridor, including variations, would cross seven areas designated as game habitat and two areas designated as wild horse or wild horse and burro management areas. Construction activities would reduce habitat in these areas. Depending on the variation, several other designated game habitat areas could be within 5 kilometers (3 miles) of a rail line in the corridor. Game animals, burros, and horses near areas of active construction would be disturbed and their migration routes could be disrupted.

Two stream or riparian areas and possibly one spring (with the Caliente Option) are within the 0.4-kilometer (0.25-mile)-wide corridor, including its variations (Table 6-50). Although no formal delineations have been made, these areas may be jurisdictional wetlands or other waters of the United States. Construction could increase sedimentation in these areas. The corridor, including its potential variations, also crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. DOE anticipates some changes to local drainage along the branch rail line and would design the rail line to accommodate existing drainage patterns.

As many as 14 springs and riparian areas occur outside the 400-meter (0.25-mile)-wide corridor and its variations, but within 5 kilometers (3 miles) of the corridor under the variations. Eight known populations of three sensitive animal species are associated with these aquatic resources. DOE anticipates that these populations would be unaffected and these areas would not be disturbed during construction or by the long-term presence of a railroad.

Soils in and adjacent to the corridor would be disturbed on approximately 12 square kilometers (3,000 acres) of land. The impacts of disturbing 12 square kilometers of soil along the 345-kilometer (214-mile)-long corridor would be transitory and small. However, several soil characteristics could influence construction activities and the amount of area disturbed. Soils susceptible to water or wind erosion occur along much of the corridor and its variations as do soils exhibiting relatively high shrink-swell characteristics (see Chapter 3, Section 3.2.2.1.4). Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by wind. Erosion control during construction and revegetation, or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is high) shrink-swell characteristics could influence the amount of area disturbed by construction if soils from outside areas had to be brought in for replacement or mixing with native soil.

As stated in Chapter 3, Section 3.2.2.1.4, variations identified for the Caliente-Chalk Mountain Corridor could avoid some biological resources, as listed in Table 6-53.

Table 6-53. Biological resources avoided by Caliente-Chalk Mountain Corridor variations.[a,b,c]

	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
Alignment variation resource	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Caliente Variation				
Sensitive species–Needle Mountain Milkvetch	0	3	0	1
Springs or groups of springs	1	14	0	1
Crestline Variation				
Sensitive species–Needle Mountain Milkvetch	0	3	0	3
Springs or groups of springs	1	14	0	4
Mercury Highway, Topopah, Mine Mountain, and Area 4 Variations				
Sensitive species				
Beatley's scorpionweed	0	17	0	17
Funeral Mountain milkvetch	0	1	0	1
Largeflower suncup	1	18	1	17
Ripley's springparsley	1	1	1	0
Mine Mountain Variation only				
Sensitive species				
Largeflower suncup	0	1	0	1
Oasis Valley springsnail	0	1	0	1
Springs or groups of springs	1	14	0	1

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.

6.3.2.2.3.4 Caliente-Chalk Mountain Rail Cultural Resources

Construction. The potential for cultural resource impacts in the Caliente-Chalk Mountain Corridor would be identical to that for the Caliente Corridor, as discussed in Section 6.3.2.2.1.4, until the Caliente-Chalk Mountain Corridor diverges at the northern boundary of the Nellis Air Force Range. From that point south the corridor passes through the Range and the Nevada Test Site to the repository site.

Archaeological site file searches have identified the presence of 100 recorded sites in the Caliente-Chalk Mountain Corridor (see Chapter 3, Section 3.2.2.1.5), including the variations (Appendix J, Section J.3.1.2). Of these, 34 are potentially eligible for inclusion in the *National Register of Historic Places*. Precise impacts to any of these resources cannot be specified until the rail alignment has been identified and its relationship to the known archaeological sites evaluated. At some point on the Nevada

Test Site, the Caliente-Chalk Mountain Corridor would intersect the 1849 Jayhawker's Emigrant Trail, but because physical expressions of the trail are unlikely, no direct impacts would occur. Although there are no known Native American resources in the corridor, there have been no field ethnographic studies. If DOE selected this corridor, this assessment of the potential for such impacts would have to wait until the completion of field studies involving Native Americans.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.3.5 Caliente-Chalk Mountain Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Caliente-Chalk Mountain branch rail line would be small (Table 6-54). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers and the public from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur in moving equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-55 lists these results.

Table 6-54. Impacts to workers from industrial hazards during rail construction and operations for the Caliente-Chalk Mountain Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	79	95
Lost workday cases	39	52
Fatalities	0.11	0.26
Noninvolved workers		
Total recordable cases	4.8	5.4
Lost workday cases	1.8	2.0
Fatalities	0.005	0.006
Totals[d]		
Total recordable cases	84	100
Lost workday cases	41	54
Fatalities	0.12	0.27

a. Totals for 43 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Caliente-Chalk Mountain rail corridor.

Table 6-56 lists the incident-free impacts, which include transportation along the corridor and along railways in Nevada leading to a Caliente-Chalk Mountain branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

6.3.2.2.3.6 Caliente-Chalk Mountain Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Caliente-Chalk Mountain Corridor.

Table 6-55. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente-Chalk Mountain Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	14,000,000	0.2	0.03
Commuting workers	61,000,000	0.6	0.08
Subtotals	*75,000,000*	*0.8*	*0.11*
Operations[c]			
Commuting workers	68,000,000	0.7	0.09
Totals	***140,000,000***	***1.5***	***0.2***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 43 months for construction.
c. Totals for 24 years for operations.

Table 6-56. Health impacts from incident-free Nevada transportation for the Caliente-Chalk Mountain implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	700	740
Estimated latent cancer fatalities	0.02	0.28	0.3
Public			
Collective dose (person-rem)	7	12	18
Estimated latent cancer fatalities	0.003	0.01	0.01
Estimated vehicle emission-related fatalities	0.002	0.0055	0.0071

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

Construction. The length of the Caliente-Chalk Mountain Corridor, 345 kilometers (214 miles), would determine the number of workers required. The construction of a branch rail line in this corridor would require workers laboring for approximately 2 million hours or about 1,000 worker-years over a 43-month construction period. The route would require four construction camps to house workers temporarily (DIRS 154822-CRWMS M&O 1998, all).

Employment

Estimated employment in the region of influence attributable to the construction of a Caliente-Chalk Mountain branch rail line, would peak in 2007 at about 647 jobs. Clark County would supply approximately 569 of the workers and Nye County would supply about 22. These additional workers would represent an increase of less than 1 percent of the Clark and Nye County employment baselines. About 56 individuals would work in Lincoln County, adding about 2.3 percent to employment in the county. DOE anticipates changes in Lincoln County's employment would be primarily the result of indirect employment caused by the presence of transient construction workers. Employment of Caliente-Chalk Mountain Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 612. The expected addition of 14,886 jobs in Clark County would be reduced by 594, and the expected growth of 330 jobs in Nye County would be reduced by 17. The expected growth of 24 jobs in Lincoln County would be reduced by 1. DOE anticipates that project-related workers not moving to Caliente-Chalk Mountain Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence attributable to the construction of a Caliente-Chalk Mountain rail line would peak in 2009 at 589 persons. Clark County would gain about 527 residents, Nye County about 24, and Lincoln County about 38. The increase in population would be less than 1 percent of the baselines for Clark, Nye, and Lincoln Counties. Because the change in the population, relative to the population baselines, would be small and transient in Clark, Nye, and Lincoln Counties, impacts to housing or schools would be unlikely.

Economic Measures

The expected peak year changes in economic measures in the region of influence attributable to a branch rail line in the Caliente-Chalk Mountain Corridor would be increases of $18.6 million in real disposable income in 2009; $30.9 million in Gross Regional Product in 2007; and $2.1 million in State and local expenditures in the last year of construction, 2009. More than 93 percent of the real disposable income and Gross Regional Product would accrue to Clark County, which would experience about 78 percent of the additional spending by State and local governments. Lincoln County would gain slightly less than 4.6 percent of the change in real disposable income, 3.7 percent of the change in Gross Regional Product, and 16 percent of the expenditures by State and local governments. The increases in each economic measure would be less than 1 percent of the baseline in each affected county, except the increase of expenditures by State and local governments in Lincoln County would be 1.1 percent. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition and Operations Period. A period of slightly slower growth in employment in the region of influence would occur from 2010 to 2012. Following this period, employment to operate a Caliente-Chalk Mountain branch rail line would stimulate growth in the region. Growth in employment in the region of influence during the transitional period would average 19 fewer jobs than would occur without a Caliente rail line. Clark County would absorb the entire slower rate of growth, with an average of 82 fewer jobs. The Clark County employment baseline would average about 1 million during this period. Nye County would gain an average of 5 jobs and Lincoln County would gain 57 jobs during this period. The job gain in Lincoln County would represent a 2.2-percent average increase over the employment baseline in the 3-year period. The employment gain in Nye County would be less than 1 percent. A Caliente-Chalk Mountain rail line would contribute to the growth in residential population throughout the transition period and into the employment base after 2012.

Employment and Population

Estimated direct employment to operate a Caliente-Chalk Mountain rail line would be 47 jobs. Increased total employment in the region of influence would average about 78 jobs over the 24-year operations period (2010 to 2033). The majority, 57, would work in Lincoln County. The increases in Lincoln County employment attributable to a Caliente-Chalk Mountain branch rail line would be 2.1 percent of the baseline. On average, 14 jobs would be created in Clark County and 6 in Nye County. The change in the population in the region from the operation of a Caliente-Chalk Mountain branch line would average about 290 persons. DOE anticipates that 99 of these individuals would settle in Lincoln County, representing a 2.1-percent increase of the population baseline for the County. An additional 171 would live in metropolitan Clark County and represent less than 1 percent of the County’s population baseline. The remaining individuals would live in Nye County and would affect the community by less than 1 percent. There would be no impacts to the school system or the housing market in Clark or Nye Counties. The increase in population in Lincoln County would add an average of about 22 students a year to the rolls of the school system. There would be no impact to housing in Lincoln County given the high housing vacancy rate in the County (see Chapter 3, Section 3.1.7.4).

Economic Measures

The estimated average, real disposable income increase attributable to the operation of a Caliente-Chalk Mountain branch rail line in the three-county region of influence would be $4.7 million per year. Contributions to real disposable personal income would range from $3.2 million in the early years of operation to $5.6 million in the last year. The annual increase in Gross Regional Product would average $4.6 million. On average, changes in real disposable income would exceed changes in Gross Regional Product. The increases in annual State and local government expenditures would average $1.6 million. The average impacts to real disposable income, Gross Regional Product, and State and local government expenditures from operating a Caliente-Chalk Mountain branch rail line would be less than 1 percent of the baselines for Clark and Nye Counties.

In Lincoln County, the changes in real disposable income and Gross Regional Product of operating a Caliente-Chalk Mountain branch rail line would range from about 1.7 percent for real disposable income to 2.6 percent for Gross Regional Product. State and local government spending would be higher by about 2.5 percent of the baseline. Workers associated with a Caliente-Chalk Mountain branch rail line would purchase many goods and services in the Lincoln County community. These dollars would continue to circulate largely within the area creating a positive economic impact. These impacts would not exceed historic short-term changes in the various socioeconomic measures.

DOE performed a detailed analysis was for the Caliente-Chalk Mountain Corridor. The results of this analysis, driven by the length of the Corridor, is representative of the potential variations (options and alternates) listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar to those listed in Table 6-48.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent during construction and by 6.9 percent during operations. Employment would rise by about 5 percent during construction and about 7.2 percent during operations. If DOE selected this rail corridor, it would initiate additional engineering and environmental studies (including socioeconomic analyses); consult with Federal, State of Nevada, Native American, and local governments; and perform additional National Environmental Policy Act reviews as a basis for constructing and operating a Caliente-Chalk Mountain Corridor.

6.3.2.2.3.7 Caliente-Chalk Mountain Rail Noise and Vibration

Over most of its length, the Caliente-Chalk Mountain Corridor passes through undeveloped land managed by the Bureau of Land Management where human inhabitants are mostly isolated ranchers and persons involved with outdoor recreation. Almost half of the corridor’s length is on the Nellis Air Force Range and Nevada Test Site, where there is little potential for noise impacts. The Caliente and Caliente-Chalk Mountain Corridors are the same in most of Lincoln County and in the northeastern part of Nye County. The Towns of Caliente and Panaca are along the eastern end of the corridor. This corridor includes the Caliente Option, Eccles Option, and Crestline Option as starting points; these are fairly remote from any rural communities.

The five variations on restricted government land (see Appendix J, Section J.3.1.2), the White River Alternate, and the Garden Valley Alternate would not affect rural communities. The variations outside restricted government land pass through areas that are farmed. Hence, some rural residences in this area could fall within the region of influence for noise.

None of the communities along the Caliente-Chalk Mountain Corridor and its nine variations (see Appendix J, Section J.3.1.2), with the exception of Caliente, would be close enough to the rail line for noise impacts to approach the noise guidelines of 50 dBA for evenings and 60 dBA during the day (Table 6-57). The Caliente Option for connecting to the Union Pacific Railroad mainline would follow an old railroad bed through the center of the Town of Caliente. Noise levels in Caliente would not differ much from existing background noise levels associated with normal rail traffic through the community. Noise levels associated with waste shipments would occur at most three times a day and probably not in a given hour. Where a branch rail line passed through Caliente, train speed would be reduced for safety and noise levels would be minimized. Traffic could be delayed at one traffic crossing in the Town of Caliente. Adverse community response to the added rail noise would be unlikely because of the long-term presence of railroad traffic in Caliente, the short trains associated with the transport of waste shipments, and the low frequency of rail shipments to and from the site.

The estimated population residing within 2 kilometers (1.3 miles) of the Caliente-Chalk Mountain Corridor in 2035 would be about 28 persons.

Vibration. Except for the historic railroad station in Caliente, which is near the existing Union Pacific Railroad mainline, the branch rail line in the Caliente-Chalk Mountain Corridor and associated variations would be sufficiently distant from historic structures, cultural ruins, and buildings to preclude building damage as a result of ground vibration. Vibration levels at reduced train speeds would be unlikely to damage the Caliente Railroad station. Moreover, the vibrations added by the relatively few trains carrying waste to Yucca Mountain at slow speeds would not add appreciably to the total vibration to

Table 6-57. Estimated propagation of noise from the operation of a waste transport train with two locomotives in communities near the Caliente-Chalk Mountain Corridor.

Corridor[a]/community	Distance (kilometers)[b]	Noise (dBA)[c]
Caliente Option		
Caliente	0	>90 at 15 meters[d]
Panaca	6[e]	26.0
Crestline Option		
Panaca	4.5[e]	26.3
Eccles Option		
Caliente	6.5[e]	<26[f]
Rachel	>20[e]	<26

a. The White River, Garden Valley, Mercury Highway, Topopah, Mine Mountain, Area 4, and Orange Blossom Road variations occur on Nellis Air Force Range or Nevada Test Site lands, too far from any community to cause noise impacts.
b. To convert kilometers to miles, multiply by 0.62137.
c. Estimated values do no include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
d. 15 meters = 49 feet.
e. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.
f. At these distances, the A-weighted sound pressure level is dominated by lower frequencies (less than 63 hertz) and would not be distinguishable from normal background levels of noise.

which the station is exposed from commercial trains that pass through Caliente. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.3.8 Caliente-Chalk Mountain Rail Utilities, Energy, and Materials

Table 6-58 lists the use of fossil fuels and other materials in the construction of a Caliente-Chalk Mountain branch rail line.

Table 6-58. Construction utilities, energy, and materials for a Caliente-Chalk Mountain branch rail line.

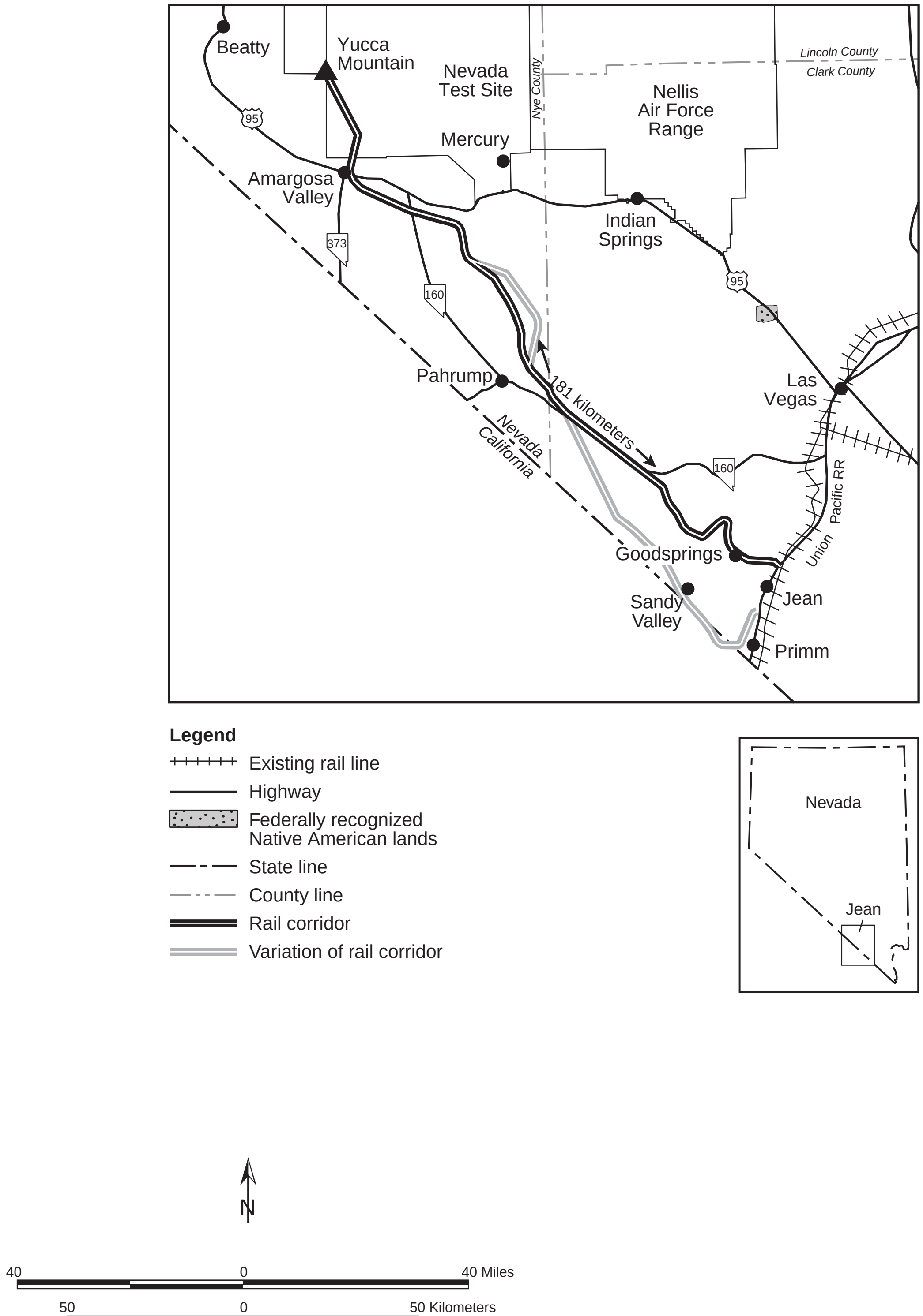
Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)[c]
340 - 370	32 - 36	610 - 680	47 - 52	280 - 310

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.4 *Jean Corridor Implementing Alternative*

The Jean Corridor originates at the existing Union Pacific mainline railroad near Jean, Nevada. It travels northwest, passing near the Towns of Pahrump and Amargosa Valley before reaching the Yucca Mountain site. The Jean Corridor is about 181 kilometers (114 miles) long from its link at the Union Pacific line to the site. Variations of the route range from 181 to 204 kilometers (112 to 127 miles). Figure 6-18 shows this corridor along with possible variations identified by engineering studies (DIRS 154822-CRWMS M&O 1998 p. 1, Item 6; see Appendix J, Section J.3.1.2). The corridor variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-18. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the same among the possible corridor variations.

The construction of a branch rail line in the corridor would require approximately 43 months. Construction would take place simultaneously at a number of locations. An estimated two construction camps would be established at roughly equal distances along the corridor. These camps would provide temporary living accommodations for construction workers and construction support facilities. A train would take about 4 hours to travel from the junction with the Union Pacific mainline to a Yucca Mountain



To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104560-YMP (1998, all).

Figure 6-18. Jean Corridor.

Repository on a Jean branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Rail Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Jean Corridor would be $462 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology, including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; and utilities, energy, and materials. Impacts that would occur to air quality and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.4.1 Jean Rail Land Use and Ownership

Table 6-59 summarizes the amount of land required for the Jean Corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-60 summarizes the amount of land required for the Jean Corridor variations and its ownership.

Table 6-59. Land use in the Jean Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	181	181 - 204
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	72 (100)	72 - 82
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	60 (83)	60 - 69
Air Force	None	None
DOE	8.5 (12)	8.5 - 8.5
Private	3.5 (5)	0.1 - 3.5
Other	None	None
Land area in 60-meter[e] *right-of-way (square kilometers)*	10.9	10.8 - 12.2
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	6.6	6.6 - 7.4
Outside 60-meter right-of-way	2.6	2.6 - 2.9

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. 60 meters = 200 feet.

Table 6-60. Variations in the Jean Corridor.[a]

Variation	Length (kilometers)[b]	Area in variation (square kilometers)[c]	Land ownership [square kilometers (percent)]	
			Bureau of Land Management	Private
Wilson Pass Option	73.5	29.4	29.4 (99.98)	0.01 (0.02)
Pahrump Valley Alternate	32.1	12.8	12.7 (99.2)	0.1 (0.8)
Stateline Pass Option	91.9	36.8	36.79 (99.97)	0.01 (0.03)

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.

Construction. The Jean Corridor (Wilson Pass Option) crosses eight Bureau of Land Management grazing allotments (Mount Stirling, Spring Mountain, Stump Springs, Table Mountain, Wheeler Wash, and three unnamed and unallotted areas); two wild horse and burro herd management areas (both in Pahrump Valley); the Old Spanish Trail/Mormon Road special recreation management area; and four areas designated as available for sale or transfer. It also crosses several telephone, pipeline, highway, and power line rights-of-way. The corridor is within 1.6 kilometers (1 mile) of the Toiyabe National Forest and three mines (Bluejay, Snowstorm, and Pilgram). The Wilson Pass Option also passes through Bureau of Land Management Class II lands in the vicinity of Wilson Pass in the Spring Mountains, potentially affecting the recreational use of this area.

The Stateline Pass Option origination location along an existing Union Pacific rail line conflicts directly with lands set aside for the proposed Ivanpah Valley Airport under the Ivanpah Valley Airport Public Lands Transfer Act (Public Law 106-362, 114 Stat. 1404). The Stateline Pass Option crosses the California-Nevada boundary line along Bureau of Land Management lands and passes near the Stateline Wilderness Area established by the California Desert Conservation Act. Construction activities could affect recreational use of the Stateline Wilderness Area. Impacts would be similar to the construction impacts discussed in Section 6.3.2.1. Corridor variations are listed in Appendix J, Section J.3.1.2. Impacts common to the rail implementing alternates are discussed in Section 6.3.2.1. The following paragraphs discuss impacts unique to this corridor.

The transfer of land from Bureau of Land Management for the Ivanpah Valley Airport would require DOE to realign the Stateline Pass Option for constructing a branch rail line.

Construction activities could affect the Old Spanish Trail/Mormon Road special recreation management area. Ease of access from one portion of the management area to the other would be reduced. These impacts could be mitigated by providing access to connect the parcels separated by the railroad right-of-way.

In the vicinity of Pahrump, Nevada, a branch rail line in the Jean Corridor would pass through approximately 9 kilometers (5.5 miles) of private property. As discussed in Section 6.3.2.1, DOE would have to make arrangements with owners to use this land. As indicated in Appendix J, Section J.3.1.2, the North Pahrump Alternate includes no private property. The North Pahrump Alternate would abut a Bureau of Land Management utility corridor and a section of the Toiyabe National Forest and could affect access to these recreational areas.

During the construction and operation and monitoring phases of the Proposed Action, there would be a potential for encroachment of the Jean Corridor by private interests. If encroachment occurred, conflicts could result as impediments to the full use of the land. Areas most likely for use by private interests are those already privately owned in the vicinity of Pahrump and those that are currently designated for sale or transfer by the Bureau of Land Management.

If DOE decided to build and operate a branch rail line in the Jean corridor, it would consult with the Bureau of Land Management and other affected agencies and with Native American tribal governments to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a right-of-way.

Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Amargosa Valley, Goodsprings, Jean, Johnnie, and Pahrump (that is, zoning and land use might differ depending on the presence or absence of a railroad). Construction of a branch rail line within the Jean corridor would require conversion of land within wild horse or wild horse and burro management areas; however, because the railroad would be unlikely to interfere with animal movements, the functionality of these areas would not be affected.

Operations. As with the other corridors, DOE expects the operation of a branch rail line in the corridor to cause fewer impacts than construction. Impacts due to rail operations would be similar to those described in Section 6.3.2.1.

6.3.2.2.4.2 Jean Rail Hydrology

Surface Water

Chapter 3, Section 3.2.2.1.3, notes that there are no surface-water resources along the Jean Corridor, including its variations.

Table 6-61 lists flood zones identified along the Jean Corridor and its variations. The Federal Emergency Management Agency maps from which DOE derived the flood zone information provided coverage for 90 percent of the corridor length. This corridor would cross seven 100-year flood zones or flood-zone groups before entering the Nevada Test Site. One of the two variations would increase the number of flood zones crossed by 1; the other segment would have no change. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Table 6-61. 100-year flood zones crossed by the Jean Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Jean to Yucca Mountain	0.6	Three tributaries leading to Roach Lake (intermittent)	Y-2
	0.7	Lovell Wash with drainage (intermittent)	Y-2
	0.4	Two unnamed washes northwest of Lovell Wash	N
	4.1	Peak Springs Alluvial Fan (dry)	N
	1.9	Wheeler Wash (dry)	N
	0.3	Wash drainage leading to Alkali Flats (dry)	N
	0.1	Rock Valley Wash (intermittent)	N
Variations			
1. Pahrump Valley Alternate	None	Located northeast of corridor.	
2. Stateline Pass Option	0.4	Crosses two tributaries to Roach Lake (dry).	
	0.8	Crosses Potasi Wash, an unnamed wash, and Lovell Wash drainage.	
	1.1	Crosses four unnamed washes and Peak Springs Fan (intermittent).	

a. Areas where natural floodwater movement could be altered and where erosion and sedimentation rates and locations could change. Sources:
   1. Federal Emergency Management Agency Flood Insurance Rate Maps for Clark and Nye Counties, Nevada.
   2. DIRS 154961-CRWMS M&O (1998, all).

b. About 10 percent of the Jean Corridor is not available on Federal Emergency Management Agency maps because a portion of the route is on the Nevada Test Site.

c. To convert kilometers to miles, multiply by 0.62137.

d. Certain 100-year flood zones can be avoided by alternative corridor segments. These are identified with a "Y" (yes) and a number representing the variation(s) that avoid the specific flood zone. The same flood zone might be crossed by both the corridor and variations at different locations. In such cases, the feature will be marked "Avoided" for the corridor route, but will appear again for the variation.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3, Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Jean Corridor passes).

The estimated amount of water needed for construction of a rail line in the corridor for soil compaction, dust control, and workforce use would be about 500,000 cubic meters (410 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 23 wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 22,000 cubic meters (18 acre-feet). Most (89 percent) of the water would be used for compaction of fill material. The estimate of fill quantities needed for construction would vary if DOE used a variation. Use of the Pahrump Valley Alternate or Stateline Pass Option would involve an increase in fill material (over that required for the corridor) and would increase the total water demand by 12 or 27 percent, respectively.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-62 summarizes the status of the hydrographic areas associated with the Jean Corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins. The use of variations would change the number of hydrographic areas crossed, but would have no effect on the portion of the corridor crossing Designated Groundwater Basins.

Table 6-62. Hydrographic areas along the Jean Corridor and its variations.

		Designated Groundwater Basins	
Description	Hydrographic areas	Number	Percent of corridor length
Jean Corridor	7	5	90
With Stateline Pass Option	6	4	90
With Pahrump Valley Alternate	7	5	90

The withdrawal of 22,000 cubic meters (18 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 23 wells along the corridor would mean that several of the hydrographic areas would have multiple wells. As indicated in Table 6-62, about 90 percent of the corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater basins. With such a large portion of the corridor over these basins, however, this would mean trucking water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources are not adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Jean corridor would require about 27,000 tanker-truck loads of water or about 14 truckloads each day for each work camp area along the corridor. Again, water obtained from permitted sources, which would provide water within allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.4.3 Jean Rail Biological Resources and Soils

Construction. The construction of a branch rail line in the Jean Corridor would disturb approximately 9.3 square kilometers (2,300 acres) of land (Table 6-59). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Table 6-63 compares the approximate area of disturbance in each land-cover type along all variations of the Jean Corridor to the area in each land-cover type in Nevada. In addition, the table lists the percentage of the area that would be disturbed. The fraction disturbed for each cover type would be very small. The disturbance would not have a discernible impact on any land-cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to that in the unvaried corridor.

Table 6-63. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Jean Corridor.[b,c]

Land-cover type	Wilson Pass Option		Stateline Pass Option		Area in Nevada	Percent disturbed
	Percent of corridor length	Land area	Percent of corridor length	Land area		
Agriculture	0	0	0	0	5,200	0
Blackbrush	18.4	1.69	0.1	0.01	9,900	0.017
Creosote-bursage	58.6	5.39	80.8	8.32	15,000	0.055
Grassland	0	0	0	0	2,800	0
Greasewood	0	0	0	0	9,500	0
Hopsage	0	0	0	0	630	0
Juniper	0	0	0	0	1,400	0
Mojave mixed scrub	21.1	1.94	14.6	1.5	5,600	0.035
Pinyon-juniper	0	0	0	0	15,000	0
Playa	0	0	0	0	7,000	0
Sagebrush	0	0	0	0	67,000	0
Sagebrush/grassland	0	0	0	0	52,000	0
Salt desert scrub	2	0.18	1.8	0.19	58,000	<0.001
Urban	ND[d]	ND	ND	ND	2,400	ND
Total[e]	100	9.2	97.3[f]	10	250,000	N/A[g]

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.
e. Totals might differ from sums of values due to rounding.
f. About 2.7 percent of land would be in California for the proposed Jean corridor with the Stateline Pass Option.
g. N/A = not applicable.

The Jean Corridor, including its variations passes through desert tortoise habitat along its entire length, so construction activities would disturb approximately 9.3 square kilometers (2,300 acres) of desert tortoise habitat, some of which is designated as critical habitat. Construction activities could kill individual desert tortoises, and the presence of a rail line could disrupt movements of individuals. The abundance of tortoises is low along much of this corridor; however, some areas in the Ivanpah, Goodsprings, Mesquite, and Pahrump Valleys have higher abundance (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411). DOE anticipates that losses would be few and would be unlikely to affect the regional population of the desert tortoise. Relocation of tortoises along the corridor prior to construction would minimize losses of individuals. DOE would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) in relation to this species if it selected this corridor and would implement all terms and conditions required by the Fish and Wildlife Service.

Two populations of Pinto beardtongue (a Bureau of Land Management sensitive species) occur in the corridor and could be affected directly or indirectly by land-clearing activities. The locations of these populations would be identified though surveys prior to disturbance and would be avoided to the extent possible. No populations of sensitive species occur in the Stateline Pass Option.

There are 33 populations of seven sensitive plant species outside the 400-meter (0.25-mile)-wide corridor, but within 5 kilometers (3 miles) of the corridor. Thirteen populations of five sensitive plant species are outside the corridor but within 5 kilometers of the Stateline Pass Option. These populations would not be affected because land disturbance would not extend to these areas. Changes in the aquatic or soil environment in these areas as a result of construction would be unlikely.

Ten designated game habitat areas for bighorn sheep, mule deer, or quail occur within the corridor and 16 areas occur within 5 kilometers (3 miles) of the corridor. The Stateline Pass Option avoids five of the designated game habitat areas in the corridor.

The Wilson Pass Option crosses three Herd Management Areas for wild horses and burros (DIRS 104593-CRWMS M&O 1999, p. 3-29). The Stateline Pass Option would avoid two of these areas. Construction activities in these areas would result in the loss of a small amount of habitat and probably would disturb animals or their movements for the duration of the activities.

No springs, perennial streams, or riparian areas occur in the Jean Corridor. Eleven springs or groups of springs are outside the corridor, but within 5 kilometers (3 miles) of the corridor. Impacts to biological resources associated with these areas are not anticipated. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States, although formal delineations have not been made (DIRS 104593-CRWMS M&O 1999, p. 3-29). DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits if necessary. The Department anticipates some changes to local drainage along the potential branch rail line and would design the rail line to accommodate existing drainage patterns.

Soils in and adjacent to the corridor would be disturbed on approximately 9.3 square kilometers (2,300 acres) of land during construction of a railroad. Impacts to soils in the corridor, including its variations [6.5 square kilometers (1,600 acres)], would be small, but could occur throughout construction. However, several soil characteristics could influence construction activities and the amount of area disturbed. Soils susceptible to wind erosion occur along much of the corridor and its variations (see Chapter 3, Section 3.2.2.1.4.). Soils considered to be highly susceptible to water erosion and having poor stability characteristics are also present, but along much smaller portions of the corridor. Disturbance of erodible soils could lead to increased silt loads in water courses or increased soil transport by wind. Erosion control during construction and revegetation, or other means of soil stabilization after construction, would minimize these concerns. The presence of soils with poor (that is, high) shrink-swell and stability characteristics could influence the amount of area disturbed by construction if soils from outside areas had to be brought in for replacement or mixing with native soil. The source of suitable fill material and the land area that would be disturbed in obtaining the material is presently unknown, so the potential for impacts to soils and biological resources associated with the borrow areas cannot be determined.

Soils classified as unstable fill also occur along portions of the Jean corridor, including its variations. The amount of land disturbance in the corridor for stabilization of a rail line and outside the corridor at the source of fill material could increase due to the presence of these soils. The source of suitable fill material and the land area that would be disturbed in obtaining the material is unknown at present, so DOE cannot determine the potential for impacts to soils and biological resources associated with the borrow areas.

As stated in Chapter 3, Section 3.2.2.1.4, variations identified for the Jean Corridor could avoid some biological resources, as listed in Table 6-64.

6.3.2.2.4.4 Jean Rail Cultural Resources

Construction. The Jean Corridor passes through the Goodsprings and Johnnie historic mining districts, and intersects the historic Yellow Pine Mining Company Railroad grade. In the southern part of the Pahrump Valley, the corridor, including the Wilson Pass and Stateline Options, crosses the Old Spanish Trail, which is under consideration for designation as a National Historic Trail. Based on Bureau of Land Management resource planning, both the Goodsprings and Pahrump Valleys are expected to contain fairly high numbers of potentially significant archaeological and historic sites. Precise impacts from rail line construction activities would be identified after completion of a cultural resource study of the corridor.

Table 6-64. Biological resources avoided by Jean Corridor variations.[a]

Alignment variation resource	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Stateline Pass Variation				
Sensitive species				
Allen's big-eared bat	0	1	0	1
Desert bearpoppy	0	3	0	1
Fringed myotis	0	1	0	1
Gila monster	0	1	0	1
Long-legged myotis	0	1	0	1
Pinto beardtongue	2	18	2	17
Sheep fleabane	0	1	0	1
Spring Mountain milkvetch	0	2	0	2
Townsend's big-eared bat	0	1	0	1
White-margined beardtongue	0	5	0	3
Yuma myotis	0	1	0	1
Game habitat				
Bighorn sheep–crucial	1	1	1	1
Bighorn sheep–migration corridor	2	0	1	0
Bighorn sheep-winter	1	7	0	3
Chukar–crucial	1	0	1	0
Mule deer–summer crucial	0	2	0	1
Mule deer–winter	2	2	1	1
Quail–crucial	3	4	1	3
Springs or groups of springs	0	11	0	5
Herd Management Units	3	0	2	0

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the corridor variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the corridor variation.

Archaeological site file searches for the Jean Corridor and its variations (Appendix J, Section J.3.1.2) revealed six recorded archaeological sites, four of which have been evaluated as being not eligible for the *National Register of Historic Places.*

There are no known Native American resources in this corridor, although the corridor passes through the traditional homelands of the Pahrump Paiute Band. In the early historic period, there were several village sites in the northern area at the base of the Spring Mountains; a branch rail line could affect some of these locations. Pending completion of field ethnographic studies, there could be other sites or resources of importance to Native Americans along this corridor that rail construction activities could affect.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.4.5 Jean Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Jean branch rail line would be small (Table 6-65). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available. Table 6-66 lists these results.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in using the Jean Corridor. Table 6-67 lists the incident-free

Table 6-65. Impacts to workers from industrial hazards during rail construction and operations for the Jean Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	67	73
Lost workday cases	33	40
Fatalities	0.09	0.20
Noninvolved workers		
Total recordable cases	4.0	4.1
Lost workday cases	1.5	1.5
Fatalities	0.004	0.004
Totals		
Total recordable cases	71	77
Lost workday cases	35	41
Fatalities	0.10	0.20

a. Totals for 43 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injury and illness.

impacts, which include transportation along the corridor and along railways in Nevada leading to a Jean branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that would not have the capability to load rail casks while operational.

6.3.2.2.4.6 Jean Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Jean Corridor.

Construction. The length of the Jean Corridor, 181 kilometers (112 miles), is the principal factor that would determine the number of workers required to construct a branch rail line. The construction of a branch rail line in this corridor would require workers laboring approximately 1.7 million hours or 855 worker years over a 43-month construction period. The workers would be temporarily housed in two construction camps (DIRS 154822-CRWMS M&O 1998, all).

Table 6-66. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Jean Corridor.

Jean	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Materials delivery vehicles	10,000,000	0.2	0.02
Commuting workers	52,000,000	0.5	0.07
Subtotals	*62,000,000*	*0.7*	*0.09*
Operations[c]			
Commuting workers	52,000,000	0.5	0.07
Totals	***110,000,000***	***1.2***	***0.16***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 43 months for construction.
c. Totals for 24 years for operations.

Table 6-67. Health impacts from incident-free Nevada transportation for the Jean Corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	720	760
Estimated latent cancer fatalities	0.02	0.29	0.3
Public			
Collective dose (person-rem)	7	150	160
Estimated latent cancer fatalities	0.003	0.08	0.08
Estimated vehicle emission-related fatalities	0.002	0.08	0.08

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

Employment

DOE anticipates that the total (direct and indirect) employment in the region of influence attributable to rail line construction would peak in 2007 at about 526 jobs. DOE anticipates that 92 percent or 483 workers, would come from Clark County. Approximately 42 workers would come from Nye County and 1 from Lincoln County. The increase in employment represents less than 1 percent of the baseline for Clark, Nye, and Lincoln Counties. Employment of Jean Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 490. The expected addition of 14,886 jobs in Clark County would be reduced by 449, and the expected growth of 330 jobs in Nye County would be reduced by 41. The expected growth of 24 jobs in Lincoln County would be unaffected. DOE anticipates that project-related workers not moving to Jean Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence attributable to the construction of a Jean branch rail line, which would lag behind increases in employment, would peak in 2009 at about 492 persons. DOE anticipates that approximately 449 would live in Clark County, 42 in Nye County, and 1 in Lincoln County. The increase in population would be less than 1 percent of each county's population baseline. Because the impacts to population in each county would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

The expected peak changes in the region of influence attributable to constructing a branch rail line in the Jean Corridor would be increases of about $15.2 million in real disposable income in 2009; about $25.7 million in Gross Regional Product in 2007; and about $1.6 million in State and local expenditures in 2009. More than 96 percent of the increases in real disposable income and Gross Regional Product and about 91 percent of the increase in State and local government expenditures would occur in Clark County. Most of the remainder of the increase would occur in Nye County. The impacts to Clark, Nye, and Lincoln Counties for each of these measures would be less than 1 percent for each county's applicable baseline. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition and Operations Period. A period of slightly slower employment growth would occur from 2010 to 2012, and then employment to operate a branch rail line would contribute to an increased rate of growth. Growth in employment in the region of influence during this transitional period would be approximately 15 fewer jobs annually than would occur without a rail line in the Jean Corridor. Clark County would experience all of the slower rate of growth. During this period, the Clark County employment baseline would be about 1 million jobs. Nye County would gain 1 job during this period. The Jean rail line would contribute to the growth in residential population throughout the transition period.

Employment and Population

Estimated direct employment for the operation of a branch rail line in the Jean Corridor would be 36 workers. The total increase in employment in the region of influence would average 54 jobs over the 24-year operation period (2010 to 2033). On average, 52 of these jobs would be in Clark County, 1 in Nye County, and none in Lincoln County. These increases represent less than 1 percent of the counties' employment baselines. An increase in the Clark and Nye County populations attributable to a Jean rail line would be about 208 individuals, 91 percent of whom would live in Clark County. The balance would live in Nye County. The impact to the baseline population in both counties would be less than 1 percent. Because the increase to the population baseline would be small, impacts to the school system or housing would be unlikely. There would be no change in employment or the number of residents in Lincoln County due to a Jean rail line.

Economic Measures

In the three-county region of influence the greatest increase in real disposable income above the baseline attributable to operations would occur in 2033, the last year of operation. This increase would be $4.3 million; the average increase in each of the 24 years of operation would be about $3.7 million. The increase in Gross Regional Product would average about $3.6 million. On average during rail line operations, changes in real disposable income would exceed changes in Gross Regional Product. Annual State and local government expenditures would average $722,000. Nearly all of the economic activity would occur in Clark County; virtually none would occur in Lincoln and Nye Counties. Annual impacts to real disposable income, Gross Regional Product, and State and local government expenditures from the operation of a branch rail line in the Jean Corridor would be less than 1 percent of the baseline for each county.

The results of the detailed analysis performed for the Jean Corridor driven by the corridor length are representative of the variations (options and alternates) listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar to those listed in Table 6-60.

6.3.2.2.4.7 Jean Rail Noise and Vibration

The Wilson Pass and Stateline Pass Options in the southern portion of the Jean Corridor and the Pahrump Valley Alternate pass through mostly U.S. Government land set aside for use by DOE or managed by the Bureau of Land Management. They also cross a small amount of private land. The Wilson Pass Option passes the communities of Amargosa Valley, Goodsprings, Jean, and Pahrump. In addition, the Stateline Pass Option passes the small communities of Sandy Valley and Primm. The smaller rural communities associated with the Jean Corridor and its variations (Appendix J, Section J.3.1.2) would be likely to experience noise levels from the operation of trains in excess of the benchmark nighttime noise level of 50 dBA, but not the daytime residential noise level of 60 dBA (Table 6-68). Jean and Primm are principally commercial business communities consisting of gaming industry, retail, and Primm businesses. In addition, the potential for growth and development in the Jean and Pahrump areas could place residents and businesses close to a Jean branch rail line, leading to noise impacts from both construction and operations.

Table 6-68. Estimated propagation of noise (dBA) from the operation of a waste transport train with two locomotives in communities near the Jean Corridor.

Corridor/community	Distance (kilometers)[a]	Noise (dBA)[b]
Wilson Pass Option		
Jean	1.6	48
Goodsprings	1.2	54
Pahrump	2.0	43
Amargosa Valley	1.0	57
Stateline Pass Option		
Stateline	1.6	48
Sandy Valley	1.0	57
Goodsprings	1.2	54
Pahrump	2.0[c]	43
Amargosa Valley	1.0	57

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (33 feet) from the tracks.
c. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.

Noise impacts for the Jean Corridor would be limited because, at distances more than 0.8 kilometer (0.5 mile) daytime noise from trains would be below noise standards for residential areas (60 dBA) and because few residents and businesses are this close to the corridor. Nonetheless, because a Jean branch rail line could pass near some communities, there would be a potential for noise impacts from both construction and operations. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passed near a community, transports could be limited to the extent necessary to ensure that noise was below levels listed as accepted noise hazards.

The estimated population that would reside within 2 kilometers (1.3 miles) of the Jean Corridor in 2035 is about 1,300 persons.

Vibration. The Jean Corridor and its variations would be distant [more than 200 meters (660 feet)] from historic structures and buildings. There are no known ruins of cultural significance along the corridor. Therefore, vibration impacts to structures would be unlikely. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.4.8 Jean Rail Aesthetics

The Wilson Pass Option of the Jean Corridor would pass through Class II lands in the Goodsprings Valley and Spring Mountains. The objective of Bureau of Land Management Visual Resource Class II lands is to preserve the existing character of the landscape. According to the Bureau, the level of changes to the landscape should be low. Management activities could be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture of the characteristic landscape. Because of this, the building of a rail line in the Wilson Pass Option probably would require more stringent construction practices to limit visual resource impacts. Although impacts due to construction activities would be short term, visual impacts to recreational land use in this area would be likely. If DOE selected this option, additional consultation with the Bureau would be necessary to address aesthetic impacts.

The operation of a branch rail line through the Class II visual resource lands in the vicinity of Wilson Pass in the Spring Mountains would draw attention to the rail line and degrade the aesthetics of the area, thereby reducing the quality of recreational use of the area.

6.3.2.2.4.9 Jean Rail Utilities, Energy, and Materials

Table 6-69 lists the use of fossil fuels and other materials in the construction of a Jean branch rail line.

Table 6-69. Construction utilities, energy, and materials for a Jean branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Jean	180 - 200	26 - 30	500 - 570	26 - 29	150 - 170

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.5 *Valley Modified Corridor Implementing Alternative*

The Valley Modified Corridor originates near the existing Apex rail siding off the Union Pacific mainline railroad. It travels northwest passing north of the City of Las Vegas, north of the Town of Indian Springs, parallel to U.S. 95 before entering the southwest corner of the Nevada Test Site and reaching the Yucca Mountain site. The Valley Modified Corridor is about 159 kilometers (98 miles) long from its link with the Union Pacific line to the site. Variations of the route range from 157 to 163 kilometers (98 to 101 miles). Figure 6-19 shows this corridor along with possible variations identified by engineering studies (DIRS 154960-CRWMS M&O 1998, all). The variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-19. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the construction and operations. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passed near a community, transports could be limited to the extent necessary to ensure that noise was below levels listed as accepted noise hazards.

The estimated population that would reside within 2 kilometers (1.3 miles) of the Jean Corridor in 2035 is about 1,300 persons.

Vibration. The Jean Corridor and its variations would be distant [more than 200 meters (660 feet)] from historic structures and buildings. There are no known ruins of cultural significance along the corridor. Therefore, vibration impacts to structures would be unlikely. The small number of trips (three per day) and the small train size would result in low levels of rail-induced ground vibration.

6.3.2.2.4.8 Jean Rail Aesthetics

The Wilson Pass Option of the Jean Corridor would pass through Class II lands in the Goodsprings Valley and Spring Mountains. The objective of Bureau of Land Management Visual Resource Class II lands is to preserve the existing character of the landscape. According to the Bureau, the level of changes to the landscape should be low. Management activities could be seen, but should not attract the attention of the casual observer. Any changes must repeat the basic elements of form, line, color, and texture of the characteristic landscape. Because of this, the building of a rail line in the Wilson Pass Option probably would require more stringent construction practices to limit visual resource impacts. Although impacts due to construction activities would be short term, visual impacts to recreational land use in this area would be likely. If DOE selected this option, additional consultation with the Bureau would be necessary to address aesthetic impacts.

The operation of a branch rail line through the Class II visual resource lands in the vicinity of Wilson Pass in the Spring Mountains would draw attention to the rail line and degrade the aesthetics of the area, thereby reducing the quality of recreational use of the area.

6.3.2.2.4.9 Jean Rail Utilities, Energy, and Materials

Table 6-69 lists the use of fossil fuels and other materials in the construction of a Jean branch rail line.

Table 6-69. Construction utilities, energy, and materials for a Jean branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Jean	180 - 200	26 - 30	500 - 570	26 - 29	150 - 170

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.2.2.5 *Valley Modified Corridor Implementing Alternative*

The Valley Modified Corridor originates near the existing Apex rail siding off the Union Pacific mainline railroad. It travels northwest passing north of the City of Las Vegas, north of the Town of Indian Springs, parallel to U.S. 95 before entering the southwest corner of the Nevada Test Site and reaching the Yucca Mountain site. The Valley Modified Corridor is about 159 kilometers (98 miles) long from its link with the Union Pacific line to the site. Variations of the route range from 157 to 163 kilometers (98 to 101 miles). Figure 6-19 shows this corridor along with possible variations identified by engineering studies (DIRS 154960-CRWMS M&O 1998, all). The variations provide flexibility in addressing engineering, land-use, or environmental resource issues that could arise in a future, more detailed survey along the corridor. This section addresses impacts that would occur along the corridor shown in Figure 6-19. With the exception of differences identified in Appendix J, Section J.3.1.2, the impacts would be generally the

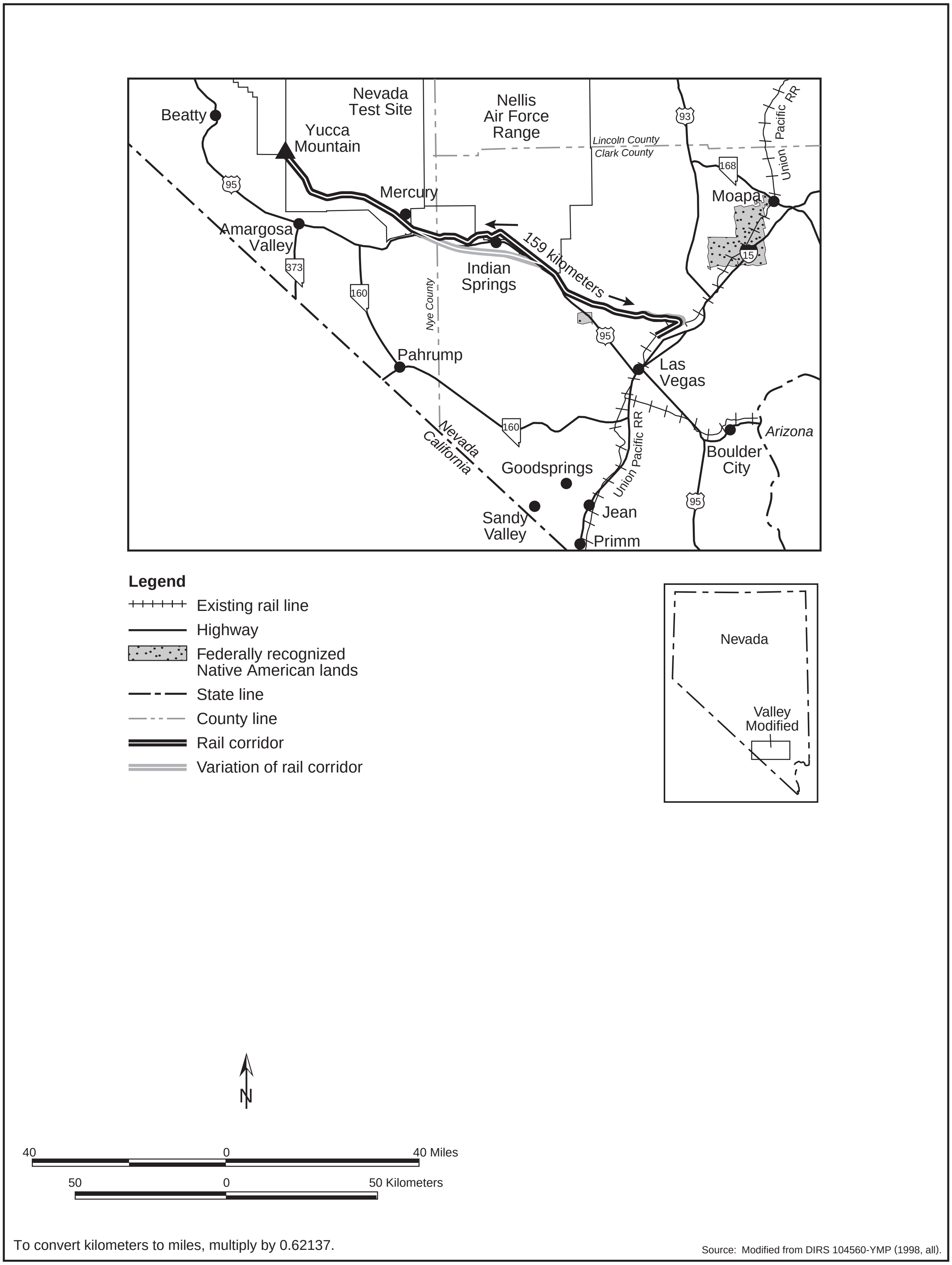


Figure 6-19. Valley Modified Corridor.

same among the possible variations. The Indian Hills Alternate of the Valley Modified Corridor also crosses the original route of the historic Las Vegas-to-Bullfrog Stage Road.

The construction of a branch rail line in the corridor would require approximately 40 months. Construction would take place simultaneously at a number of locations along the corridor. Two construction camps would be established to provide temporary living accommodations for construction workers and construction support facilities. A train would take about 3 hours to travel from the junction with the Union Pacific mainline to the Yucca Mountain Repository on a Valley Modified branch rail line (DIRS 101214-CRWMS M&O 1996, Volume 1, Section 4, Branch Rail Operations Plan). The estimated life-cycle cost to construct and operate a branch rail line in the Valley Modified Corridor would be $283 million in 2001 dollars.

The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to aesthetics, and waste management would be the same as those discussed in Section 6.3.2.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.2.2.5.1 Valley Modified Rail Land Use and Ownership

Table 6-70 summarizes the amount of land required for the Valley Modified corridor, its ownership, and the estimated amount of land that would be disturbed, as well as ranges for the variations. Table 6-71 summarizes the amount of land required for the variations of the Valley Modified Corridor and its ownership.

Table 6-70. Land use in the Valley Modified Corridor.[a]

Factor	Corridor (percent)	Range due to variations
Corridor length (kilometers)[b]	159	157 - 163
Land area in 400-meter[c]*-wide corridor (square kilometers)*[d]	63 (100)	63 - 65
Land ownership in 400-meter-wide corridor (square kilometers)		
Bureau of Land Management	34 (53)[e]	29.9 - 36.7
Air Force	7 (11)	3.6 - 7.5
DOE	21 (32)	20. 6 - 20.6
Private	0.2 (0.3)	0 - 0.18
Fish and Wildlife Service	1.8 (3)	1.7 - 4.1
Land area in 60-meter[f] *right-of-way (square kilometers)*	9.6	9.4 - 9.8
Disturbed land (square kilometers)		
Inside 60-meter right-of-way	4.4	4.3 - 4.5
Outside 60-meter right-of-way	0.6	0.68 - 0.7

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. 400 meters = about 0.25 mile.
d. To convert square kilometers to acres, multiply by 247.1.
e. Percentages do not total 100 due to rounding.
f. 60 meters = 200 feet.

Construction. The corridor crosses three Bureau of Land Management grazing allotments (Wheeler Slope, Indian Springs, and Las Vegas Valley), two wilderness study areas (Nellis ABC and Quail Spring, both recommended by the Bureau as unsuitable for inclusion in the National Wilderness System), and one area designated as available for sale or transfer (DIRS 104993-CRWMS M&O 1999, Table 7, p. 22). It also crosses several telephone, pipeline, highway, and power line rights-of-way, and the Nellis Air Force Base small arms range. Impacts common to rail implementing alternates are discussed in Section 6.3.2.1. The following paragraphs discuss impacts unique to this corridor.

Table 6-71. Variations in the Valley Modified Corridor.[a]

Variation	Length (kilometers)[b]	Land area in variation (square kilometers)[c]	Land ownership [square kilometers (percent)] Bureau of Land Management	Fish and Wildlife Service	Department of Defense	Private
Indian Hills Alternate	45.2	18.1	18.1 (100)	--[d]	--	--
Sheep Mountain Alternate	23.3	9.8	3.2 (33)	3.4 (35)	3.1 (32)	--
Valley Connection	21.1	2.7	2.5 (93)	--	0.01 (0.4)	0.2 (6.6)

a. Source: DIRS 155549-Skorska (2001, all).
b. To convert kilometers to miles, multiply by 0.62137.
c. To convert square kilometers to acres, multiply by 247.1.
d. -- = none.

Variations to this corridor are listed in Appendix J, Section J.3.1.2. The Indian Hills Alternate would avoid Nellis Air Force Range by traveling south of Indian Springs. This variation would cross Fish and Wildlife Service lands and pass almost entirely within a Bureau of Land Management utility corridor. It would also pass through a Bureau Land Withdrawal Area (N50945) for a power project. The Sheep Mountain Alternate would pass through the Nellis Small Arms Range and Nellis Wilderness Study Areas A, B, and C, as well as the Quail Mountain Wilderness Study Area and the Desert National Wildlife Range. Although the Bureau considers these Wilderness Study Areas unsuitable for inclusion in the National Wilderness System, DOE would have to consult with the Bureau before it could build a branch rail line.

The corridor passes along the Las Vegas metropolitan area's northern boundary, in an area that is currently undergoing growth and where future commercial and residential growth might occur. However, metropolitan area growth might not extend to the corridor area until after the operations phase of the repository, when DOE assumes that it would no longer have use for a branch rail line. The corridor also passes next to the Dry Lake siding and within about 1.6 kilometers (1 mile) of the Las Vegas Paiute Indian Reservation north of Las Vegas. There would be no significant land-use impact to this reservation because of its distance from the corridor.

During the construction and operation and monitoring phases of the Proposed Action, there would be a potential for encroachment of the Valley Modified Corridor by private interests. If encroachment occurred, conflicts could result as impediments to the full use of lands. Areas most likely for use by private interests are those currently designated for sale or transfer by the Bureau of Land Management.

Two segments of the corridor encroach slightly on the Nellis Air Force Range. The U.S. Air Force has noted the potential for safety risks of crossing lands that are hazard areas and encompass weapons safety footprints for live weapons deployment. DOE has identified the Indian Hills Alternate, which would avoid the larger encroachment (see Appendix J, Section J.3.1.2). If DOE decided to build and operate a branch rail line in the Valley Modified corridor, it would consult with the Bureau of Land Management, U.S. Air Force, other affected agencies and Native American Tribal governments, and other DOE program operations on the Nevada Test Site to help ensure that it avoided or mitigated potential land-use conflicts associated with alignment of a rail line right-of-way. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65; 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to build and operate a branch rail line through any part of the Range.

Although there are no known community development plans that would conflict with the rail line, the presence of a rail line could influence future development and land use along the railroad in the communities of Indian Springs and North Las Vegas (that is, zoning and land use might differ depending on the presence or absence of a railroad).

Operations. DOE anticipates that operations along the Valley Modified Corridor would cause fewer impacts than construction. Operations impacts would be similar to those discussed in Section 6.3.2.1.

6.3.2.2.5.2 Valley Modified Rail Air Quality

Construction. The Valley Modified Corridor and some of its variations would involve construction in the Las Vegas Valley air basin, which is in nonattainment for particulate matter (PM_{10}) and carbon monoxide (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54). To assess nonradiological air quality impacts from branch rail line construction in this air basin, DOE compared emissions from earthmoving activities and vehicles to General Conformity and Prevention of Significant Deterioration thresholds. Appendix G, Section G.1.4.1, describes the method used to determine PM_{10} emissions from earthmoving activities. This method takes no credit for dust suppression measures; however, the analysis for transportation construction activities included dust suppression measures. Appendix G, Section G.1.4.5 describes the method used to determine criteria pollutant emissions from construction vehicle activity which, for the Valley Modified Corridor, would consume an estimated 7.1 million liters (about 1.9 million gallons) of diesel fuel and 150,000 liters (38,000 gallons) of gasoline in the nonattainment area over the length of the construction period.

Eighty-four kilometers (52 miles) of the total 160 kilometers (98 miles) of a branch rail line in the Valley Modified Corridor would be in the nonattainment area. Table 6-72 lists emission rates of PM_{10} and carbon monoxide from earthmoving activities and vehicle emissions in the nonattainment area assuming a work crew completed this section over 21 months and used standard construction techniques. There would be five borrow areas, five spoils areas, and one construction camp along the 84-kilometer (52-mile) construction corridor. Estimated emission rates would exceed the PM_{10} General Conformity threshold for a nonattainment area (see Table 6-73). The PM_{10} exceedance would primarily be the result of earthmoving activities. Dust abatement measures, assumed to be 70 percent effective (DIRS 155557-Clark County 2001, p. 4-63), would reduce emissions by a significant amount.

Table 6-72. Emission rates from Valley Modified Corridor construction in the nonattainment area.

Activity and emission	Emission rate (kilograms per year)
Earthmoving, PM_{10}	110,000
Vehicle, PM_{10}	14,000
Vehicle, carbon monoxide	98,000

a. To convert kilograms to pounds, multiply by 2.2046.

Table 6-73. Particulate matter (PM_{10}) and carbon monoxide air quality impacts (kilograms per year)[a] from Valley Modified Corridor construction in the nonattainment area.

Criteria pollutant/threshold	Threshold level[b]	Percent of threshold[c]		
		Earthmoving	Vehicles	Total
PM_{10}				
General Conformity	63,500 (serious)	170	22	190
Prevention of Significant Deterioration	227,000	48	6	54
Carbon monoxide				
General Conformity	90,700	NA[d]	110	110
Prevention of Significant Deterioration	227,000	NA	43	43

a. Kilograms per year; to convert kilograms to pounds, multiply by 2.2046.
b. Sources: 40 CFR 52.21 and 93.153.
c. Numbers are rounded to two significant figures.
d. NA = not applicable.

If DOE selected the Valley Modified Corridor for the construction and operation of a branch rail line, the final plans, specifications, and estimates would require adherence to the Clark County Health District PM_{10} emissions control measures. These measures are being developed in the Particulate Matter State Implementation Plan (DIRS 155557-Clark County 2001, all). Implementation of the comprehensive measures should enable rail line construction to start. The purpose of the measures under development is not to prohibit construction activity, but to enable it within the Environmental Protection Agency air quality requirements. Because the estimated impacts to air quality in the Las Vegas Valley air basin would exceed the General Conformity thresholds for carbon monoxide and PM_{10} in a nonattainment area, DOE would have to implement mitigation measures if it selected the Valley Modified Corridor. Under the construction design analyzed above, one crew at a time would construct the branch rail line from beginning to end over about 40 months, and the emissions in the Las Vegas Valley air basin would occur over about 21 months. A potential mitigation measure would be to have two crews construct the line at half the pace from each end of the corridor. Under this plan, the emissions in the basin would occur over the full 40 months, which would result in a decrease of about half in the emission rates, which would reduce the impacts listed above to levels at or less than the General Conformity thresholds. In addition, as part of final construction planning DOE would plan to use dust control measures and ensure fuel efficiency to reduce emissions. These measures should result in emissions below the General Conformity threshold levels.

The Valley Modified Corridor includes the Indian Hills Alternate, Sheep Mountain Alternate, and Valley Connection. The Sheep Mountain Alternate and Valley Connection are entirely in the nonattainment area, whereas only half of the Indian Hills Alternate is in the nonattainment area. The rail extents of the Indian Hill Alternate and the Valley Modified Corridor in the nonattainment area are equivalent. Therefore, no greater or smaller air quality impacts would result from selection of the Indian Hill Alternate. The Sheep Mountain Alternate and Valley Connection, if used, would add 3 and 7 kilometers (1.9 and 4.3 miles) of rail, respectively, to the length of the Corridor. Therefore, air quality impacts would be slightly but not significantly (less than 10 percent) greater if these variations were used.

Operations. Fuel consumption by diesel train engines operating along the rail corridor would emit carbon monoxide, nitrogen dioxide, and particulate matter (PM_{10} and $PM_{2.5}$). Based on the Federal standards for locomotives (40 CFR 92.005), there are no emission standards for sulfur dioxide.

In attainment areas, the pollutant concentrations in the air would increase slightly during the passage of a train, but the emissions from one or two trains a day would not exceed the ambient air quality standards. However, the Valley Modified Corridor would include a route through the Las Vegas Valley air basin, which is in nonattainment for carbon monoxide and PM_{10}. The air quality impacts to this air basin from train operation along the Valley Modified Corridor would be a small contribution in comparison to the amount of pollutants emitted by automotive travel in the basin. Thus, emissions from train operations in the Las Vegas Valley air basin would not produce further violations of the ambient air quality standards.

6.3.2.2.5.3 Valley Modified Rail Hydrology

Surface Water

Chapter 3, Section 3.2.2.1.3, notes that there are no surface-water resources along the Valley Modified Corridor, including its variations.

Table 6-74 lists flood zones identified along the Valley Modified Corridor and its variations. The Federal Emergency Management Agency maps from which DOE derived the flood zone information provided coverage for about 75 percent of the corridor length. The corridor crosses only two different 100-year flood zones or flood zone groups before entering the Nevada Test Site. Of the three variations, the Indian Hills Alternate would lessen the number of flood zones to one; the other two segments would have no change. As indicated in Section 6.3.2.1, impacts associated with altering drainage patterns or changing erosion and sedimentation rates or locations would be minor and localized.

Groundwater

Construction. The water used during construction would come largely from groundwater resources. The annual demands would be a fraction of the perennial yields of most producing aquifers (Chapter 3,

Table 6-74. 100-year flood zones crossed by the Valley Modified Corridor and its variations.[a,b]

Corridor portion	Crossing distance (kilometers)[c]	Flood zone feature(s)	Avoided by variation[d] (Yes or No)
Dry Lake to Yucca Mountain	0.1[e]	Unnamed creek NW of the city of Las Vegas (intermittent)	N
	1.2[f]	Drainage (projected) west of Indian Springs Air Force Auxiliary Base (intermittent)	Y-3
Variation			
1. Valley Connection	None	Located at the origin of the corridor	
2. Sheep Mountain Alternate	None	Located to the north of the corridor	
3. Indian Hills Alternate	None	Located to the south of the corridor	

a. Areas where natural floodwater movement could be altered and where erosion and sedimentation rates and locations could change. Sources:
 1. Federal Emergency Management Agency Flood Insurance Rate Maps for Clark and Nye Counties, Nevada.
 2. DIRS 154961-CRWMS M&O (1998, all).
b. Approximately 25 percent of the Valley Modified Corridor is not available on Federal Emergency Management Agency maps because that portion of the route is on the Nevada Test Site and the Nellis Air Force Range.
c. To convert kilometers to miles, multiply by 0.62137.
d. Certain 100-year flood zones can be avoided by corridor variations. These are identified with a “Y” (yes) and a number representing the specific variation(s) from the second half of the table that avoids the specific flood zone.
e. Limited information due to the Nellis Air Force Range.
f. Projected from limited data. Specific area not covered by Federal Emergency Management Agency maps; values were extrapolated from the closest maps.

Section 3.2.2.1.3, discusses estimated perennial yields for the hydrographic areas over which the Valley Modified corridor passes).

The estimated amount of water needed for construction of a rail line in the Valley Modified Corridor for soil compaction, dust control, and workforce use would be about 395,000 cubic meters (320 acre-feet) (DIRS 104914-DOE 1998, all). For planning purposes, DOE assumed that this water would come from 20 groundwater wells installed along the corridor. The average amount of water withdrawn from each well would be approximately 20,000 cubic meters (16 acre-feet). Most (90 percent) of the water would be used for compaction of fill material. The estimate of fill quantities needed for construction would vary if DOE used either of the variations. The Indian Hills Alternate would increase the total water demand for the Valley Modified Corridor, but only by 6 percent.

Chapter 3, Section 3.2.2.1.3, discusses the hydrographic areas over which the Valley Modified Corridor would pass, their perennial yields, and whether the State of Nevada considers each a Designated Groundwater Basin. If the hydrographic area is a Designated Groundwater Basin, permitted groundwater rights approach or exceed the estimated perennial yield, depleting the basin and water resources or requiring additional administration. Table 6-75 summarizes the designation status of the hydrographic areas associated with the Valley Modified Corridor and the approximate portion of the corridor that passes over Designated Groundwater Basins. Use of either variation would make no notable change in the status of hydrographic areas crossed.

Table 6-75. Hydrographic areas along the Valley Modified Corridor and its variations.[a]

		Designated Groundwater Basins	
Corridor description	Hydrographic areas	Number	Percent of corridor length
Valley Modified Corridor	6	3	70
Variations	6	3	70

a. All three variations (Indian Hills Alternate, Sheep Mountain Alternate, and Valley Connection) would cross the same six hydrographic areas (two with slightly different crossing distances) and the same three designated groundwater basins which, rounded to the nearest 10 percent, would represent the same portion of the total corridor.

The withdrawal of 20,000 cubic meters (16 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the corridor based on their perennial yields (Chapter 3, Section 3.2.2.1.3). However, the installation of 20 wells along the corridor would mean that hydrographic areas would have multiple wells. As indicated in Table 6-75, about 70 percent of the corridor length is over Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for groundwater depletion. This does not mean that DOE could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Because the DOE requests would be for a short-term construction action, the State Engineer would have even more discretion. Rather than spacing the wells evenly along the corridor, DOE could use locations that would make maximum use of groundwater areas that are not Designated Groundwater Basins. With such a large portion of the corridor over these basins, however, this would mean trucking water for long distances. Another option would be to lease temporary water rights from individuals along the corridor. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources are not adversely affected.

As an alternative, DOE could transport water by truck to meet construction needs. The construction of a branch rail line in the Valley Modified corridor would require about 21,000 tanker-truck loads of water or about 20 truckloads each day. Again, water obtained from permitted sources, which would provide water in allocations determined by the Nevada State Engineer, would not affect groundwater resources.

Operations. Operations along a completed rail line would have little impact on groundwater resources. Possible changes in recharge, if any, would be the same as those at the completion of construction.

6.3.2.2.5.4 Valley Modified Rail Biological Resources and Soils

Construction. The construction of a rail line in the Valley Modified corridor, including its variations, would disturb approximately 5 square kilometers (1,200 acres) of land (Table 6-71). The analysis assumed that the types of land cover in disturbed areas outside the corridor would be the same as that within the corridor. Table 6-76 compares the approximate area of disturbance in each land-cover type along the Valley Modified Corridor, including its possible variations, to the amount of land area within each land-cover type in Nevada. In addition, the table lists the percentage of the area that would be disturbed. The fraction disturbed for each cover type would be very small. The disturbance would not have a discernible impact on any land-cover type. Although some alignment variations could lead to a small increase in the total amount of land disturbed, the portion of the corridor, including its variations, in each land-cover type would be similar to that in the corridor.

This corridor, including its variations, passes through desert tortoise habitat along its entire length, so construction activities would disturb approximately 5 square kilometers (1,200 acres) of desert tortoise habitat, some of which is designated as critical habitat. Construction activities could kill individual desert tortoises, and the presence of a rail line could disrupt movements of individuals. However, desert tortoise abundance is low along this corridor (DIRS 101521-BLM 1992, Map 3-13; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411) so losses would be few, and would be unlikely to affect the regional population. Relocation of tortoises along the route prior to construction would minimize losses of individuals. The long-term presence of a rail line could block movements of individual tortoises. DOE would consult with the Fish and Wildlife Service (under Section 7 of the Endangered Species Act) regarding this species if it selected this corridor, and would implement all terms and conditions required by the Service.

Two populations of Parish scorpionweed and one of Ripley's springparsley (a Bureau of Land Management sensitive species) occur in the corridor and could be affected directly or indirectly by land-clearing activities. The locations of these populations would be identified though surveys prior to disturbance and would be avoided to the extent possible.

Table 6-76. Maximum area disturbed (square kilometers)[a] in each land-cover type for the Valley Modified Corridor.[b,c]

Land cover type	Percent of corridor length	Area disturbed	Area in Nevada	Percent disturbed
Agriculture	0.0	0.00	5,200	0.00
Blackbrush	0.0	0.00	9,900	0.00
Creosote-bursage	79.0	4.03	15,000	0.026
Grassland	0.0	0.00	2,800	0.00
Greasewood	0.0	0.00	9,500	0.00
Hopsage	0.0	0.00	630	0.00
Juniper	0.0	0.00	1,400	0.00
Mojave mixed scrub	15.9	0.81	5,600	0.014
Pinyon-juniper	0.0	0.00	15,000	0.00
Playa	0.6	0.03	7,000	<0.001
Sagebrush	0.0	0.00	67,000	0.0
Sagebrush/grassland	0.0	0.00	52,000	0.0
Salt desert scrub	4.5	0.23	58,000	<0.001
Urban		ND[d]	2,400	ND

a. To convert square kilometers to acres, multiply by 247.1.
b. Based on the proportion of the route in each land-cover type; percent disturbed was based on the variation with the greatest disturbance within a particular land-cover type. Percentages add to more than 100 because maximum values were used.
c. Source: DIRS 104593-CRWMS M&O (1999, Appendix D).
d. ND = not determined.

There are 46 populations of 11 sensitive plant species outside of the 400-meter (0.25-mile)-wide corridor, but within 5 kilometers (3 miles) of Sheep Mountain Alternate (see Appendix J, Section J.3.1.2 for a list of corridor variations). An additional five populations of two sensitive plant species are outside the corridor but within 5 kilometers of the Indian Hills Alternate. The use of either alternate would avoid one population of desert bearpoppy. These populations would not be affected because land disturbance would not extend to these areas and changes would be unlikely in the aquatic or soil environment as a result of construction or the long-term presence of a railroad.

Several designated game habitat areas for bighorn sheep, mule deer, or quail occur within 5 kilometers (3 miles) of the corridor. Larger game animals occupy large home ranges and could easily traverse the distance between the designated habitat and the corridor. Construction activities probably would disturb individuals or groups of animals and they would avoid construction areas.

The Indian Hills Alternate would cross one herd management area for wild horses and burros (DIRS 104593-CRWMS M&O 1999, p. 3-29). Construction in this area would result in the loss of a small amount of habitat and probably would disturb animals or their movements for the duration of the activity.

No springs, perennial streams, or riparian areas occur in this corridor or its variations and, therefore, impacts to biological resources associated with these areas and located within 5 kilometers (3 miles) of the corridor would be unlikely. The corridor and variations cross a number of ephemeral streams that may be classified as waters of the United States, although no formal delineations have been made (DIRS 104593-CRWMS M&O 1999, p. 3-29). DOE would work with the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, if necessary. Some changes to local drainage along a branch rail line would be likely; DOE would design the rail line to accommodate existing drainage patterns.

This corridor would cross two Wilderness Study Areas. Construction of a railroad in these areas would be incompatible with a Wilderness designation. Although the Bureau considers these Wilderness Study

Areas unsuitable for inclusion in the National Wilderness System, DOE would have to consult with the Bureau before it could build a branch rail line.

Soils in and adjacent to the corridor would be disturbed on approximately 5 square kilometers (1,200 acres) of land during construction of the railroad. Impacts to soils in the corridor [4.4 square kilometers (1,100 acres)] would be small, but could occur throughout construction. Impacts to disturbed areas outside the corridor would be transitory. DOE could reclaim these areas as practicable.

Shrink-swell soils occur along much of the corridor, including its variations, as does the potential for blowing soils. The presence of such soils could influence the amount of area disturbed by construction because soils in the vicinity of the railroad would have to be stabilized. Disturbance during construction would increase the amount of soil that could be transported by wind because the existing vegetation would be disturbed, at least temporarily. Revegetation after construction or other means of soil stabilization could minimize the amount of wind-borne soil.

As stated in Chapter 3, Section 3.2.2.1.4, variations identified for the Valley Modified Corridor could avoid some biological resources, as listed in Table 6-77.

Table 6-77. Biological resources avoided by Valley Modified Corridor variations.[a]

	Occurrence of resource			
	For unvaried segment of corridor		Occurrence avoided by variation	
Alignment variation resource	In corridor[b]	Within 5 km[c]	In corridor	Within 5 km
Sheep Mountain Alternate				
Sensitive species–desert bearpoppy	0	1	0	11
Indian Hills Alternate				
Sensitive species–desert bearpoppy	0	1	0	11

a. Variations listed are those that would result in the avoidance of biological resources along the corridor.
b. In the corridor [or springs within 400 meters (0.25 mile)], but avoided by the variation.
c. Within 5 kilometers (3 miles) of the corridor, but more than 5 kilometers from the variation.

6.3.2.2.5.5 Valley Modified Rail Cultural Resources

Construction. Cultural field studies in the area of the Valley Modified Corridor indicated that the area crossed by the corridor has the potential for relatively high densities of archaeological and historic sites. The corridor, including the Sheep Mountain Alternate, passes within 3 kilometers (1.9 miles) of three properties listed on the *National Register of Historic Places*: Tule Springs Archaeological Site, Tule Springs Ranch District, and the Corn Creek Campsite (DIRS 155826-Nickens and Hartwell 2001, Table 6). Direct impacts on these properties from rail line construction activities would be unlikely. The Bureau of Land Management Las Vegas District predicts that the Indian Springs Valley has the highest possible density of unrecorded significant cultural resources in Clark County. An archaeological records search yielded 19 previously recorded sites along the corridor and its variations (see Appendix J, Section J.3.1.2), 11 of which are considered potentially eligible for the *National Register of Historic Places* (Chapter 3, Section 3.2.2.1.5). Known historic sites that could be affected by rail construction activities include early railroad construction camps along the Union Pacific line near Apex and the historic Las Vegas and Tonopah Railroad (unvaried corridor segment, Sheep Mountain Alternate, and Indian Springs Alternate), as well as the original grade of that railroad. This corridor passes through Camp Desert Rock, a significant historic military site southwest of Mercury.

The Southern Paiute used Indian Springs Valley. There were several early historic period villages at springs such as Indian Springs, Tule Springs, and Corn Creek, and at other locations north of Las Vegas. Some of these locations could be affected by rail line construction activities along the corridor or the Sheep Mountain or Indian Hills Alternates.

The Valley Modified Corridor passes within about 1 kilometer (0.6 mile) of the Las Vegas Paiute Indian Reservation in the northeastern part of the Las Vegas Valley. The corridor would not affect identified cultural resources on the reservation.

Operations. As stated in Section 6.3.2.1, additional impacts to these resources during the operation of the branch rail line would be unlikely.

6.3.2.2.5.6 Valley Modified Rail Occupational and Public Health and Safety

Construction. Industrial safety impacts on workers from the construction and use of the Valley Modified branch rail line would be small (Table 6-78). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, and fatalities to workers from construction and operation activities. The analysis also evaluated traffic fatality impacts that would occur during the moving of equipment and materials for construction, worker commutes to and from construction sites, and transport of water to construction sites if wells were not available (Table 6-79).

Table 6-78. Impacts to workers from industrial hazards during rail construction and operations for the Valley Modified Corridor.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved worker		
Total recordable cases[c]	32	73
Lost workday cases	16	40
Fatalities	0.04	0.20
Noninvolved worker		
Total recordable cases	1.9	4.1
Lost workday cases	0.7	1.5
Fatalities	0.002	0.004
Totals		
Total recordable cases	34	77
Lost workday cases	16	41
Fatalities	0.05	0.20

a. Totals for 40 months for construction.
b. Totals for 24 years for operations.
c. Total recordable cases includes injuries and illness.

Operations. Incident-free radiological impacts would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste in the Valley Modified rail corridor. Table 6-80 lists the incident-free impacts, which include transportation along the Valley Modified corridor and along railways in Nevada leading to a Valley Modified branch line. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

6.3.2.2.5.7 Valley Modified Rail Socioeconomics

The following paragraphs discuss potential socioeconomic impacts associated with the construction and operation of a branch rail line in the Valley Modified Corridor.

Construction. The length of the Valley Modified Corridor, 159 kilometers (98 miles), is the most important factor that would determine the number of construction workers required. The construction of a branch rail line in this corridor would require workers laboring for approximately 810,000 hours or 405 worker years during the 40-month construction period. This rail line would require two temporary construction camps to house workers (DIRS 104595-CRWMS M&O 1999, all).

Employment

DOE anticipates that the total (direct and indirect) employment in the region of influence would peak in 2007 at about 245 jobs. Approximately 243 of the workers would come from Clark County, 2 from Nye County, and none from Lincoln County. The increase in employment would represent less than 1 percent of the employment baselines. Employment of Valley Modified Corridor construction workers and some indirect support workers would end in 2009. As a result, the projected total growth (2009 to 2010) of 15,240 jobs in the region of influence would be reduced by 191. The expected addition of 14,886 jobs in Clark County would be reduced by 189, and the expected growth of 330 jobs in Nye County would be reduced by 2. The expected growth of 24 jobs in Lincoln County would be unaffected. DOE anticipates

Table 6-79. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Valley Modified Corridor.

Activity	Kilometers[a]	Traffic fatalities	Emissions fatalities
Construction[b]			
Material delivery vehicles	8,000,000	0.1	0.02
Commuting workers	24,000,000	0.2	0.03
Subtotals	*32,000,000*	*0.4*	*0.05*
Operations[c]			
Commuting workers	52,000,000	0.5	0.07
Totals	***84,000,000***	***0.9***	***0.12***

a. To convert kilometers to miles, multiply by 0.62137.
b. Totals for 40 months for construction.
c. Totals for 24 years for operations.

Table 6-80. Health impacts from incident-free Nevada transportation for the Valley Modified Corridor implementing alternative.[a]

Category	Legal-weight truck shipments	Rail shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	670	710
Estimated latent cancer fatalities	0.02	0.27	0.28
Public			
Collective dose (person-rem)	7	20	26
Estimated latent cancer fatalities	0.003	0.01	0.01
Estimated vehicle emission-related fatalities	0.002	0.009	0.011

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

that project-related workers not moving to Valley Modified Corridor operational jobs would be absorbed in other work in the State. These changes in employment would represent less than 1 percent of the applicable baselines.

Population

Population increases in the region of influence from the construction of a Valley Modified branch rail line, which would lag behind increases in employment, would peak in 2009 at about 219 persons. About 216 persons would reside in Clark County and 3 in Nye County. Population increases would be unlikely in Lincoln County. The impact to the population would be less than 1 percent of the Clark and Nye County population baselines. Because the expected increase in population would be so small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Real disposable income, Gross Regional Product, and State and local government expenditures would rise during construction. The expected peak change in annual levels of these economic measures in the region of influence for a Valley Modified Corridor would be about $7.4 million in 2009 for real disposable income; $12.5 million in 2007 for Gross Regional Product; and $722,000 in 2009 for State and local expenditures. The impacts of these changes would be primarily confined to Clark County, where the workers would live and where they would purchase goods and services. The construction-related impacts would be less than 1 percent of the baseline values for all measures. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition and Operations Period. As the economy bridged the period between construction and operation of a Valley Modified branch rail line, the region of influence would continue to experience growth in the labor force and in residential population.

Employment and Population
Estimated direct employment for the operation of a branch rail line in the Valley Modified Corridor would average 36 workers. Total increase in employment in the three-county region of influence would average about 52 jobs over the 24-year operations period (2010 to 2033). DOE anticipates that all jobs would be in Clark County. In the region of influence, the average change in population during operations would be about 137 persons, 134 of whom would reside in Clark County. The impact to Clark County population and employment would be less than 1 percent of the baselines. Because the impact from increases in employment and population would be small, impacts to schools or housing would be unlikely.

Economic Measures
In the region of influence the greatest estimated increase in real disposable income attributable to the operation of a branch rail line in the Valley Modified Corridor ($3.6 million) would occur in 2033; the average increase for the 24-year operation would be $3.1 million. The change in real disposable income would be less than 1 percent of the baseline in the three counties. The average increase in Gross Regional Product would be about $3.6 million, or less than 1 percent of the baselines. The average State and local government expenditures would be approximately $482,000. The impact of additional expenditures by State and local governments would be less than 1 percent of the baselines. Virtually all of the economic activity related to the branch rail line would occur in Clark County.

The results of the detailed analysis performed for the Valley Modified Corridor, driven by the length of the corridor, are representative of the variations listed in Appendix J, Section J.3.1.2. The lengths of the variations are similar those listed in Table 6-71.

6.3.2.2.5.8 Valley Modified Rail Noise and Vibration
The Valley Modified Corridor passes north of Las Vegas and follows U.S. Highway 95 west past the small communities of Indian Springs, Cactus Springs, and Mercury (a Federal installation). Over its full length, the corridor is on Federal land set aside for use by DOE or the U.S. Air Force or managed by the Bureau of Land Management. Land west of the North Las Vegas area has few farms and most of the land is undeveloped.

The corridor meets the Union Pacific mainline near the Apex and Dike sidings in northeast Clark County. The County and the Bureau of Land Management have set aside land for an industrial park in this area. The nighttime noise benchmark of 50 dBA would be exceeded by estimated noise levels north of Las Vegas (Table 6-81). The corridor passes within 1 kilometer (0.6 mile) of the Las Vegas Paiute Indian Reservation. The Indian Hills Alternate (Appendix J, Section J.3.1.2) passes about 0.5 kilometer (0.3 mile) south of the Nevada penal institution at Indian Springs. Estimated noise levels at the penal institution from the Indian Springs Alternate would be 65 dBA.

Because a branch rail line would pass near some communities (including the Indian Springs penal institution), there would be a potential for noise impacts from both construction and operations. Corridor variations west of Indian Springs would not affect rural communities (Appendix J, Section J.3.1.2). The estimated population residing within 2 kilometers (1.3 miles) of the Valley Modified Corridor in 2035 would be about 190 persons. As discussed in Section 6.3.2.1, in areas where a branch rail line or variation passes near a community, train speeds could be limited to the extent necessary to ensure that noise was below levels listed as accepted noise standards.

Vibration. The Valley Modified branch rail line and its variations would be distant [more than 200 meters (660 feet)] from historic structures and buildings. There are no known ruins of cultural significance along the corridor. Therefore, vibration impacts to structures would be unlikely. The small number of trips (two per day) and the small train size would result in low levels of rail-induced ground vibration.

Table 6-81. Estimated propagation of noise (dBA) from the operation of a waste transport train with two locomotives in communities near the Valley Modified Corridor.[a]

Corridor/community	Distance (kilometers)[a]	Estimated noise (dBA)[b]
Valley Modified		
North Las Vegas	1	57
Indian Springs	1.6	48.1
Cactus Springs	1.8	45.5
Indian Springs Alternate		
Indian Springs	2[c]	43.1
Cactus Springs	4[c]	27.6
Mercury[d]	2[c]	43.1

a. To convert kilometers to miles, multiply by 0.62137.
b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
c. Noise estimates at distances greater than 2 kilometers (1.2 miles) have large uncertainty.
d. Federal installation.

6.3.2.2.5.9 Valley Modified Rail Utilities, Energy, and Materials

Table 6-82 lists the use of fossil fuels and other materials in the construction of a Valley Modified branch rail line.

Table 6-82. Construction utilities, energy, and materials for a Valley Modified branch rail line.

Route	Length (kilometers)[a]	Diesel fuel use (million liters)[b]	Gasoline use (thousand liters)	Steel (thousand metric tons)[c]	Concrete (thousand metric tons)
Valley Modified	160	13 - 14	270 - 280	22 - 23	130

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.

6.3.3 IMPACTS OF NEVADA HEAVY-HAUL TRUCK TRANSPORTATION IMPLEMENTING ALTERNATIVES

This section describes the analysis of human health and safety and environmental impacts for five implementing alternatives that would employ heavy-haul trucks to transport rail shipping casks containing spent nuclear fuel and high-level radioactive waste in Nevada. DOE has identified five highway routes in Nevada for potential use by the heavy-haul trucks to transport the casks. The casks would be transported to the repository from an intermodal transfer station along a mainline railroad where they would be loaded onto the heavy-haul trucks from railcars. The trucks would also transport empty casks from the repository back to the intermodal transfer station for loading back onto railcars.

INTERMODAL TRANSFER STATION AND NAVAL SPENT NUCLEAR FUEL

Under the mostly legal-weight truck scenario, DOE would use the services of a commercial intermodal operator for the transfer of naval spent nuclear fuel shipments. This EIS assumed that DOE would not build an intermodal transfer station to handle those shipments. Because only 300 naval spent nuclear fuel casks would arrive in Nevada by rail over 24 years, the impacts of intermodal transfer operations would be considerably less than those for the mostly rail scenario. On average, the intermodal transfers would occur for about 2 weeks every 5 months to remove five casks from each train shipment. A staff of 20 would work only during these rail shipments.

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b. Estimated values do not include noise loss due to interactions with the ground that could account for decreases in estimated noise levels of from 10 to 20 dBA at 100 meters (330 feet) from the tracks.
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DOE would locate an intermodal transfer station at one of three potential locations in Nevada near existing rail lines and highways: (1) near Caliente, (2) northeast of Las Vegas (Apex/Dry Lake), or (3) southwest of Las Vegas (Sloan/Jean). Caliente is the originating location for three of the routes that heavy-haul trucks could use to ship spent nuclear fuel and high-level radioactive waste to the repository. There is one potential route each associated with the Apex/Dry Lake and Sloan/Jean locations (Figure 6-20).

For convenience and as shown in the figure, the five highway routes have been named the Caliente, Caliente/Chalk Mountain, Caliente/Las Vegas, Apex/Dry Lake, and Sloan/Jean routes. DOE considers these routes to be feasible for heavy-haul trucks to use in transporting large rail casks to and from the repository. The routes were compiled from a selection of highways in Nevada that the State has designated for use by heavy-haul trucks (DIRS 155347-CRWMS M&O 1999, Request #046). They include highways that were identified in a study by the College of Engineering at the University of Nevada, Reno, for the Nevada Department of Transportation (DIRS 103072-Ardila-Coulson 1989, all). This study provided a "preliminary identification of Nevada highway routes that could be used to transport current shipments of Highway Route-Controlled Quantities of Radioactive Materials and high-level radioactive waste." They also include highways studied by the Transportation Research Center at the University of Nevada, Las Vegas, that characterized "rail and highway routes which may be used for shipments of high-level nuclear waste to a proposed repository at Yucca Mountain, Nevada" (DIRS 103462-Souleyrette, Sathisan, and di Bartolo 1991, all).

This section evaluates impacts in Nevada for each route and associated intermodal transfer station. The evaluation addresses (1) upgrading highways to accommodate frequent heavy-haul truck shipments, (2) constructing and operating an intermodal transfer station, and (3) making heavy-haul truck shipments. With the exception of Interstate System Highways, upgrades to existing Nevada highways would be necessary to accommodate the heavy-haul trucks.

The analysis of impacts for each of the five Nevada heavy-haul truck implementing alternatives assumed the national mostly rail transportation scenario. Therefore, the analysis included the impacts of legal-weight truck transportation from six commercial generators that do not have the capability to handle or load a large rail cask. About 1,079 legal-weight truck shipments would enter Nevada and travel to the repository. These trucks would use the same transport routes and carry about the same amounts of spent nuclear fuel per shipment as those for the mostly legal-weight truck scenario discussed in Section 6.3.1.

The analysis evaluates impacts for the following environmental resource areas: land use and ownership; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; utilities, energy, and materials; and waste management.

Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.1 Impacts Common to Nevada Heavy-Haul Truck Implementing Alternatives

Nevada highways upgraded for heavy-haul truck use would allow routine, safe use in year-round operations. Upgrades would include reconstruction of some highway sections, especially in areas where spring and fall thaws and freezes make the highways susceptible to damage by heavy vehicles (frost-restricted areas). In addition, new turnout lanes at frequent intervals along two-lane highways would allow other traffic to pass the slower heavy-haul vehicles. Highway shoulders would be widened and road surfaces would be improved in many areas. Interstate highways would not be improved because they already meet standards that upgrades to other Nevada highways for heavy-haul truck shipments would follow.

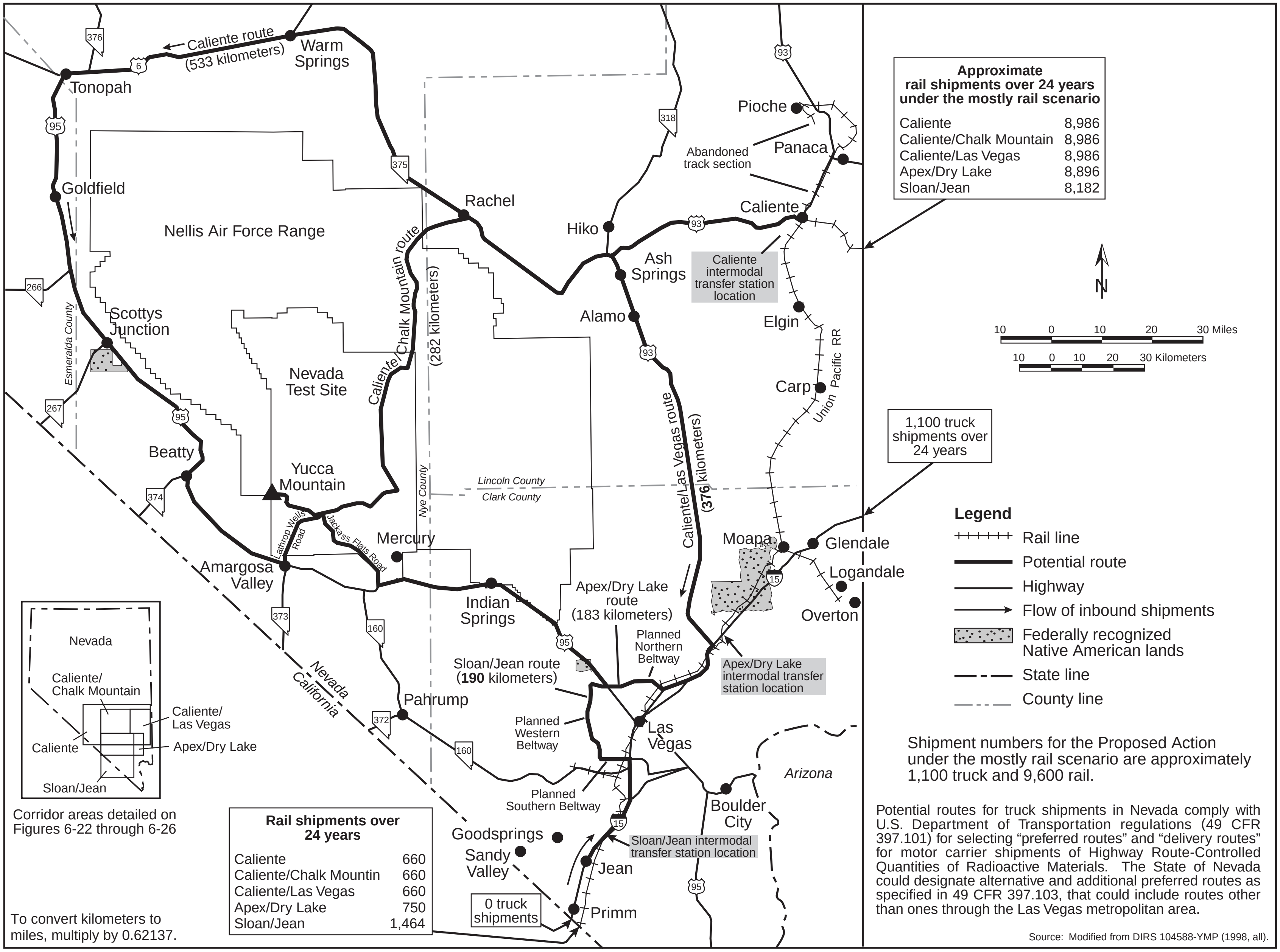


Figure 6-20. Potential routes in Nevada for heavy-haul trucks and estimated number of shipments for each route.

Even with the highway upgrades, heavy-haul trucks would cause delays for other vehicles because of their size and slower travel speeds. On most of the highways in Nevada that heavy-haul shipments would use, traffic volumes are classified as *level of service Class A* (DIRS 103255-CRWMS M&O 1999, p. 3-11), which means that traffic flows freely without delay (see Chapter 3, Section 3.2.2.2.11, for a description of all levels of service). The addition of 11 round trips each week to the traffic flow on these highways would not lead to a change in the average level of service. However, some traffic in lanes traveling with the vehicles would experience delays and short queues could form between turnout areas. In congested areas, such as the Las Vegas metropolitan area, where the level of service for the planned Las Vegas Beltway could be Class C or lower during non-rush-hour times, large slow-moving vehicles with their accompanying escort vehicles could present a temporary but large obstruction to traffic flow. Because disruptions on congested highways often continue after the removal of the cause, the duration of a traffic flow disruption would be longer than the time the vehicle would travel on the highway.

An intermodal transfer station would be common to all five heavy-haul truck implementing alternatives. Figure 6-21 shows the locations in Nevada that DOE is considering for such a station. Station construction would take about 18 months. The station would be a fenced area of about 250 by 250 meters (820 by 820 feet) and a rail siding that would be about 2 kilometers (1.25 miles) long. The estimated total area occupied by the facility and support areas would be 200,000 square meters (50 acres). It would include rail tracks, two shipping cask transfer cranes (one on a gantry rail and a backup rubber-tired vehicle), an office building, and a maintenance and security building. It would also have connecting tracks to an existing mainline railroad and storage and transfer tracks inside the station boundary. The maintenance building would provide space for routine service and minor repairs to the heavy-haul trailers and tractors. The station would have power, water, and other services. Diesel generators would provide a backup electric power source. The station would have the capacity to allow an intermodal transfer rate of 22 rail casks a week (11 loaded casks to the repository, 11 empty casks returned to the commercial and DOE sites).

Operations at an intermodal transfer station would include switching railcars carrying spent nuclear fuel and high-level radioactive waste casks from mainline railroad trains to the station's side track; queuing railcars on the side track for movement to the intermodal transfer area; moving railcars carrying loaded casks from the side track into position to transfer the casks to heavy-haul trucks; and using the facility crane to transfer loaded casks from railcars to heavy-haul trucks. The station would reverse this sequence of operations for empty casks returning from the repository.

The estimated life-cycle cost to construct and operate an intermodal transfer station and to operate heavy-haul trucks in Nevada would range from $387 million to $669 million (2001 dollars), depending on the alternative.

This section discusses impacts for the analysis areas that would be common to all five heavy-haul truck implementing alternatives. It includes impacts for upgrading Nevada highways for use by heavy-haul trucks, constructing and operating an intermodal transfer station, and heavy-haul truck transportation of shipping casks, both loaded and empty. DOE evaluated these impacts as described in Section 6.3. Section 6.3.3.2 discusses impacts that would be unique to each heavy-haul truck transportation implementing alternative.

6.3.3.1.1 *Common Route Land Use and Ownership Impacts*

Intermodal Transfer Station Construction. Land-use impacts from an intermodal transfer station would center on the station itself because the railroad lines and the highways that DOE would use already exist and their intended use would not change. The construction of an intermodal transfer station would change the land uses and ownership (organizational control) of about 0.2 square kilometer (50 acres) of property. This land would become the responsibility of DOE or possibly a transportation operating

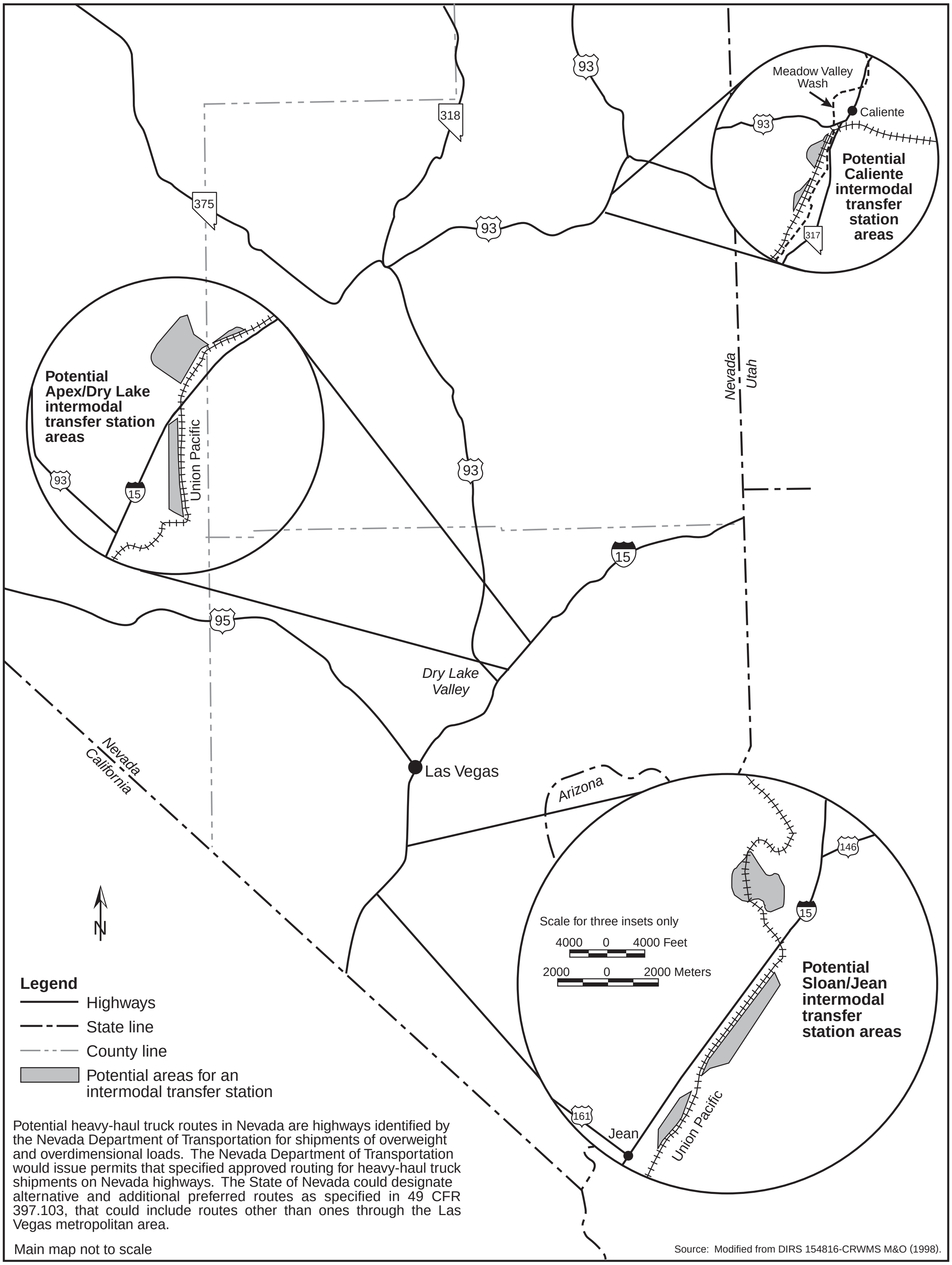


Figure 6-21. Potential locations for an intermodal transfer station.

company. An intermodal transfer station would be in an area used for industrial and commercial activities or adjacent to existing roads and railways. Because the land area would be small, fencing around an intermodal transfer station would have no significant impacts on other land uses. Because of the station's use and proximity to industrial and commercial facilities or existing roads and rail lines, land use impacts would be small. DOE would build a Caliente intermodal transfer station, located near the entrance to Kershaw-Ryan State Park, on lands currently used for industrial and commercial purposes. Because of this, there should be no additional impact to land use.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Intermodal transfer station operations (arriving and departing trains, arriving and departing heavy-haul trucks, intermodal transfers, and maintenance and inspection activities) would be confined to the same areas that were disturbed during construction, so no additional land disturbance would take place. There would be no significant impacts to land use of the proposed facility locations. Only limited land-use impacts would result from heavy-haul truck operations on Nevada highways. Erosion along these highways would be managed as it is now. Because new road construction would not be needed, additional land and soil disturbance would occur only along existing roads and within existing rights-of way. Other land-use and ownership impacts would differ among the implementing alternatives. These impacts are described in Section 6.3.3.2.

6.3.3.1.2 *Common Route Air Quality Impacts*

The emissions of criteria pollutants [carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter (PM_{10}), lead, and ozone] are regulated under the Clean Air Act. Ozone would not be directly released during heavy-haul truck route construction and operation activities. However, ozone precursors (nitrogen dioxide and volatile organic carbon compounds) would be released due to fuel use by construction equipment. The estimated annual emission rates of nitrogen dioxide and volatile organic carbon compounds would be small in comparison with regulatory standards (40 CFR 52.21). In addition, lead emissions would not result from heavy-haul truck route construction and operation activities. The construction and operation activities discussed in this section would not be a significant source of ozone or lead.

DOE conducted a conformity review using the guidance in DIRS 155566-DOE (2000, all) for transportation activities under the heavy-haul truck implementing alternative. This review focused on the emission of carbon monoxide and PM_{10}. The Las Vegas air basin is in nonattainment status for carbon monoxide, which is largely a result of on-road sources (DIRS 156706-Clark County 2000, Appendix A, Table 1-3). During construction, transportation of personnel, materials, and supplies; construction of an intermodal transfer station; and highway construction and upgrade activities in the nonattainment area (including accelerated construction of the Las Vegas Beltway) would result in carbon monoxide emissions in the nonattainment area. During operations, transportation of personnel, materials, and supplies and transportation of spent nuclear fuel and high-level radioactive waste would result in carbon monoxide emissions in the nonattainment area. The review determined that during the construction phase total carbon monoxide emissions would exceed the General Conformity threshold level in the nonattainment area only for the Caliente/Las Vegas route (110 percent of threshold). All other nonattainment area construction and operations emissions in the nonattainment area would not exceed the General Conformity threshold level. The maximum emissions would be 100 metric tons (110 tons) per year (110 percent of threshold) during construction ; this estimate is 0.11 percent of the 2000 daily carbon monoxide inventory of the Las Vegas air basin. Maximum total emissions during operations would be 73 metric tons (80 tons) per year (80 percent of threshold); this estimate is 0.08 percent of the 2000 daily carbon monoxide inventory of the Las Vegas air basin.

The Las Vegas air basin is also in nonattainment status for PM_{10}, which is largely a result of construction activities (DIRS 155557-Clark County 2001, Tables 3-8 and 5-3). The conformity review determined that the fugitive dust emissions from the construction of the intermodal transfer facilities and highway construction and upgrade activities in the nonattainment area (including accelerated construction of the Las Vegas Beltway) would just exceed General Conformity threshold levels for the Caliente/Las Vegas route (100 percent of threshold). The maximum emissions would be 66 metric tons (73 tons) per year (100 percent of threshold) during construction; this estimate is 0.04 percent of the annual and daily 2001 PM_{10} inventory of the Las Vegas air basin.

The General Conformity Threshold levels are exceeded for carbon monoxide (110 percent of threshold) and PM_{10} (100 percent of threshold) during construction of the Caliente/Las Vegas route. The above-threshold emissions would occur over a 1.2-year period in the nonattainment area. During the remaining construction time for this route, construction activities and, therefore, emissions would occur largely outside the nonattainment area. Outside the nonattainment area, emissions levels would be significantly below the Prevention of Significant Deterioration levels (carbon monoxide—43 percent of threshold and PM_{10}—29 percent of threshold).

The DIRS 155112-Berger (2000, p. 56) estimate for transportation of radioactive materials only for heavy-haul truck transport for 2020 is 0.54 metric ton (0.59 ton) per day. The Berger estimate is largely the result of emissions from collateral traffic congestion. Although DOE believes the estimate is high, a value of 0.54 metric ton per day, 11 round trip shipments per week, 52 weeks per year, would result in about 123 metric tons (135 tons) of carbon monoxide per year, which would exceed the 91 metric tons (100 tons) per year General Conformity threshold, but would be 0.08 percent of the annual and daily 2001 PM_{10} inventory of the Las Vegas air basin.

Highway Construction and Upgrades. Construction and upgrade activities would occur in Nevada along any of the five heavy-haul alternatives (see disturbed area estimates under the Land Use and Ownership discussions in Section 6.3.3.2. These activities would result in the release of criteria pollutants. Fuel consumption during construction activities would result in releases of criteria pollutants [carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter (PM_{10})]. Construction activities would also release particulate matter in the form of fugitive dust from such activities as excavation and truck traffic. The analysis for the three heavy-haul truck routes that would pass through the Las Vegas Valley air basin included acceleration of the Las Vegas Beltway project from its scheduled completion in 2020 to a completion date of 2010.

Most of the road upgrades would occur in areas that are in attainment for all criteria pollutants. If construction activities were conducted in the Las Vegas Basin, which is in nonattainment for PM_{10} and carbon monoxide, additional measures would be necessary to reduce the PM_{10} and carbon-monoxide emissions, in accordance with the Clark County PM_{10} State Implementation Plan (DIRS 155557-Clark County 2001, all). Appendix G, Section G.1.4.1, describes the method used to determine PM_{10} emissions from earthmoving activities. This method takes no credit for dust suppression measures. However, the analysis assumed dust suppression for the transportation construction emissions described here and in the conformity review; dust suppression was assumed to reduce PM_{10} emissions by 70 percent. Appendix G, Section G.1.4.5, describes the method used to determine criteria pollutant emissions from construction vehicle activity. Fuel consumption from route-specific construction vehicle use is assumed to be:

Caliente/Las Vegas route:	5.5 million liters (1.5 million gallons) diesel fuel, 110,000 liters (29,000 gallons) gasoline over 46 months
Sloan/Jean route:	1.7 million liters (450,000 gallons) diesel fuel, 29,000 liters (7,700 gallons) gasoline over 48 months
Apex/Dry Lake route:	1.6 million liters (420,000 gallons) diesel fuel, 25,000 liters (7,400 gallons) gasoline over 28 months

Accelerated Northern Beltway:	1.9 million liters (500,000 gallons) diesel fuel, 35,000 liters (9,200 gallons) gasoline over 28 months (add these emissions to Caliente/Las Vegas and Apex/Dry Lake results)
Accelerated Southern and Western Beltway:	3.9 million liters (1 million gallons) diesel fuel, 72,000 liters (19,000 gallons) gasoline over 48 months (add these emissions to Sloan/Jean results)

However, activities at any location would generate transient emissions that would be spread over a very large area because construction would be a moving source along various portions of the route. Construction activities in or near the nonattainment area would include intermodal transfer facility construction at Sloan/Jean and Apex/Dry Lake; highway upgrade activities for the Caliente/Las Vegas, Sloan/Jean, and Apex/Dry Lake routes; and accelerated Las Vegas Beltway construction.

Intermodal Transfer Station Construction. Construction of an intermodal transfer station would also generate emissions of criteria pollutants from fuel use and earthmoving activities. Each heavy-haul truck route would require the construction of such a facility. The Caliente intermodal transfer station could serve the Caliente, Caliente/Chalk Mountain, or Caliente/Las Vegas route. The Caliente station would be in an area in attainment of the National Ambient Air Quality Criteria (attainment area) and construction emissions would adhere to the Prevention of Significant Deterioration regulations (40 CFR 52.21). The Sloan/Jean or Apex/Dry Lake station would be in or near the Las Vegas Basin PM_{10} and carbon monoxide nonattainment area. New stationary emission sources in nonattainment areas are regulated under the General Conformity Rule (40 CFR 93.153).

Table 6-83 lists estimated annual emissions from the construction of an intermodal transfer station. These estimates would apply to each of the three potential site areas. Building an intermodal transfer station would disturb about 0.2 square kilometer (50 acres) over 18 months. Construction of the station would require about 130,000 liters (34,000 gallons) of diesel fuel and about 2,600 liters (690 gallons) of gasoline. The analysis used the method described above for highway construction and upgrades to estimate emissions from earthmoving and fuel use.

Table 6-83. Annual criteria pollutant releases from construction of an intermodal transfer station (kilograms per year).[a]

Pollutant	Construction emission (annual)	PSD limit[b]	Percent of limit[b]	GCR[c] emission threshold	Percent of GCR emission threshold
Nitrogen dioxide	3,400	230,000	1.4	NA[d]	NA
Sulfur dioxide	320	230,000	0.14	NA	NA
Carbon monoxide	2,100	230,000	0.91	91,000	2.3
PM_{10}	9,400	230,000	4.1	64,000 (serious)	15

a. To convert kilograms to tons, multiply by 0.0011023.
b. Prevention of Significant Deterioration (40 CFR 52.21).
c. GCR = General Conformity Rule (40 CFR 93). Applies for releases of pollutants in areas in nonattainment.
d. NA = not applicable.

Table 6-83 lists the percentage of each pollutant in relation to the Prevention of Significant Deterioration limit and the General Conformity Rule emission threshold. The estimated annual releases from the construction of the intermodal transfer station would be almost 4 percent of the Prevention of Significant Deterioration limit and 15 percent of the General Conformity Rule emission threshold (see 40 CFR 93) for PM_{10} and 2.3 percent for carbon monoxide. Construction activities in the Las Vegas nonattainment area would have to follow more stringent fugitive dust (PM_{10}) control measures described in the Clark County PM_{10} State Implementation Plan (DIRS 155557-Clark County 2001, all).

Heavy-Haul Truck and Intermodal Transfer Station Operations. Operations at the intermodal transfer station would include locomotive and heavy-haul truck emissions. Fuel use by heavy-haul trucks would result in emissions of carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM_{10}. Based on the Federal standards for switch locomotives (40 CFR 92.006), there are no emission standards for sulfur dioxide. The locomotive would operate about 30 hours per week at the intermodal transfer station. The pollutant concentration in the area around the route would increase slightly during the passage of the heavy-haul trucks but would not exceed the General Conformity thresholds. About 11 heavy-haul trucks per week would travel to and from the intermodal transfer station.

Table 6-84 lists estimated annual emissions from the operation of an intermodal transfer station. These estimates would apply to each location.

Table 6-84. Annual emissions of criteria pollutants from operation of an intermodal transfer station over 24 years (kilograms per year).[a]

Pollutant	Operation[b] emissions (annual)	PSD limit[c]	Percent of PSD limit	GCR[d] emission threshold	Percent of GCR emission threshold
Nitrogen dioxide	38,000	230,000	17	NA[e]	NA
Sulfur dioxide	(f)	230,000	(f)	NA	NA
Carbon monoxide	11,000	230,000	4.8	91,000	12
Particulate matter (PM_{10})	1,100	230,000	0.48	64,000	1.7

a. To convert kilograms to tons, multiply by 0.0011023.
b. Operations emissions from a switchyard locomotive and heavy-haul trucks.
c. PSD limit = Prevention of Significant Deterioration definition of a major stationary source (40 CFR 52.21); applies for releases of criteria pollutants during operation.
d. GCR = General Conformity Rule (40 CFR Part 93); applies for releases of pollutants in areas in nonattainment.
e. NA = not applicable.
f. 40 CFR 92.006 does not define sulfur dioxide emission standards for locomotives.

The estimated annual releases for the operation of the intermodal transfer station would be about 17 percent or less of the definition of a major stationary source (see Chapter 3, Section 3.1.2.1, or 40 CFR 52.21). The operation of a midroute stopover would result only in small releases of pollutants.

The operation of a yard locomotive would not emit ozone directly, but would emit ozone precursors (nitrogen dioxide and hydrocarbons). The estimated annual releases of the ozone precursors would be small; nitrogen dioxide would be about 17 percent of a major stationary source. Therefore, DOE does not expect the operation of the intermodal transfer facility to be a significant source of ozone.

Because the shipping casks would not be opened, there would be no radiological air quality impacts from normal operations at an intermodal transfer station.

Other air quality impacts would differ among the implementing alternatives (see Section 6.3.3.2).

6.3.3.1.3 *Common Route Hydrology Impacts*

This section describes impacts common to the five heavy-haul truck implementing alternatives (including upgrades to Nevada highways and construction of a midroute stopover and an intermodal transfer station at one of three locations) for surface water and groundwater.

Surface Water

Highway Construction and Upgrades. For road improvement work and construction of a midroute stopover, a contractor could place fuel tank trucks or trailers along the route to support equipment operations. Such a practice would present some potential for spills and releases. As long as the contractor met the regulatory requirements for reporting and remediating spills and properly disposing of or recycling used materials, the probability of unrecovered spills due to negligence or improper work practices would be low. If a release occurred, the potential for chemical contaminants (principally petroleum products) to enter flowing surface water before cleanup would be the largest risk. Surface-water resources along routes for heavy-haul trucks and in the vicinity of intermodal transfer station sites are identified in Chapter 3, Section 3.2.2.2.3. Among all the routes and station sites, three identified surface-water resources cross or run immediately adjacent to a route and two others are as close as 10 to 30 meters (30 to 100 feet). Otherwise, all of the identified surface-water resources are at least 100 meters (330 feet) from the existing roads or intermodal transfer station sites. Two of the station sites and their associated routes for heavy-haul trucks (Sloan/Jean and Apex/Dry Lake) have no identified surface-water resources within 1 kilometer (0.6 mile). The potential for released contaminants to reach flowing surface water would be very low.

A portable asphalt plant to support roadway improvement work would be located along the paving area. Aggregate crushing plants would be located in borrow areas. DOE assumes that the borrow areas would be those normally used by the Nevada Department of Transportation. Spills and releases of asphalt materials, which are predominantly petroleum products but include chemical additives, could occur in the course of operating an asphalt plant. Spill reporting and remediation requirements would be in place for these operations, as described above. Once asphalt was in place, it would be susceptible to minor leaching or bleeding while it cured, similar to the leaching or bleeding that occurs during road construction for other highway projects.

Intermodal Transfer Station Construction. Potential impacts to surface water would include (1) the possible spread of contamination by precipitation, intermittent runoff events, or, where present, releases to flowing water in the single perennial stream, and (2) the alteration of natural drainage patterns or runoff rates that could affect downgradient resources.

Materials that could contaminate surface water would be present during construction; these would consist primarily of petroleum products (fuels and lubricants) and coolants (antifreeze) to support equipment operations. There would not be much bulk storage of these materials. Fuel for vehicles would be purchased from nearby commercial vendors. Minor amounts of building materials such as paints, solvents, and thinners could be present during construction.

The construction of an intermodal transfer station would include stormwater runoff control, as necessary; the completed station would have a stormwater detention basin. These measures would minimize the potential for contaminated runoff to reach a stream.

Appendix L contains a floodplain/wetlands assessment that examines the effects of highway route construction, operation, and maintenance (see Section L.4.1) on the following floodplains in the vicinity of Yucca Mountain: Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash. There are no delineated wetlands at Yucca Mountain.

The assessment in Appendix L compares what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6, L.3.2.7, L.3.2.8, and L.4.2.2). In general, wetlands have not been delineated at the three sites. The Appendix L assessment does not evaluate potential floodplain or wetland effects along routes for heavy-haul trucks because these are existing roads and DOE assumed upgrades would be limited to those construction activities necessary to accommodate the heavy-haul vehicles. If DOE selected heavy-haul trucks to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site, it would also select one of five routes (Figure 6-20) and one of three alternative intermodal transfer station sites (Figure 6-21). DOE would then prepare a more detailed floodplain/wetlands assessment of the selected alternatives to determine to what extent the routes and station locations might be subject to flooding and whether the upgrades would affect wetlands.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Surface-water impacts during operations would be limited to those from maintaining and resurfacing highways and parking areas at a midroute stopover that the heavy-haul trucks would use. As discussed above, good construction practices overseen by the Nevada Department of Transportation would limit impacts that could result from spills of chemical contaminants in the course of highway maintenance and resurfacing activities. Contamination of surface water caused by contaminants leached from new asphalt would be similar to that which occurs in the periodic resurfacing of asphalt highways.

Operations at a completed intermodal transfer station would have little impact on surface waters beyond any permanent drainage alterations that occurred during construction. The station area runoff rates would differ from those of the natural or existing terrain but, given the relatively small size [0.2 square kilometer (50 acres)] of the potentially affected area, they would add little to overall runoff quantities for the area.

The general design criteria for a station would consider the potential for a 100-year flood. Because the spent nuclear fuel and high-level radioactive waste shipping casks would not be opened or otherwise disassembled, the use of industrial design standards for this facility would be appropriate. The analysis assumes that the station would have a diesel-powered generator to provide standby electric power and an associated diesel storage tank. The diesel tank would present a minor potential for spills and releases. Runoff retention areas would limit impacts of potential oil and diesel spills in parking areas.

6.3.3.1.4 *Common Route Groundwater Impacts*

Highway Construction and Upgrades. For highway upgrades, the most likely impacts would be changes to infiltration rates and new sources of contamination that could migrate to groundwater during construction. In this case, however, the potential for impacts would be small due to the relatively small areas affected by upgrading and the fact that highway construction [with the exception of 2 kilometers (1.2 miles) of new highway near Beatty, Nevada, and a midroute stopover], would be a modification of existing roadways. In addition, there would be no large sources of contamination.

Construction activities would disturb and loosen the ground, which could produce greater infiltration rates. However, this impact would be minor and short-lived as contractors completed their work and stabilized the disturbed areas.

Intermodal Transfer Station Construction. Construction activities for an intermodal transfer station would disturb and loosen the ground for some time, which could cause higher infiltration rates. However, this impact would be minor and short-lived as contractors completed the facility and stabilized the disturbed areas.

Water needs for construction would be met by trucking water to the site, installing a well (which would also be used for operations), or possibly by connection to a local water distribution system. In any case, water demand would be small for construction.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The use of highways by heavy-haul trucks would have little impact on groundwater resources. There would be no continued need for water along the route, and there would be no changes to recharge beyond those at the completion of construction.

The operation of a completed midroute stopover and an intermodal transfer station would have little impact on groundwater. Infiltration rates would be as described above for the completion of construction;

the relatively small size of the facilities would minimize changes. Potential sources of contamination at the intermodal transfer station would consist primarily of a diesel fuel tank for the standby generator and heavy equipment. Water demand at the station and the midroute stopover would be small, consisting primarily of the needs of the operators, and would be obtained by the methods described above for construction. This demand would cause no noticeable change in water consumption rates for the area.

Other impacts to hydrology would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.5 *Common Route Biological Resources and Soils Impacts*

Highway Construction and Upgrades. Highway upgrade activities would involve improving existing road surfaces and possibly building a bridge near Beatty, Nevada (Caliente route), a midroute stopover (Caliente routes), and about 2 kilometers (1.2 miles) of new highway to handle heavier vehicles (DIRS 155347-CRWMS M&O 1999, Request #048). Areas disturbed by these activities would be in, adjacent to, or near existing rights-of-way. These areas would consist of habitats previously degraded by human activities, which would limit impacts associated with the routes. Clearing of vegetation and soil disturbance would create habitat for colonization by exotic plant species that are present along the candidate routes. This could result in an increase in abundance of exotic species along the routes, which could result in suppression of native species and increased fuel loads for fire. Reclamation of disturbed areas would enhance the recovery of native vegetation and reduce colonization by exotic species. Slight alterations of habitat immediately adjacent to existing roads would have only small impacts on desert tortoises because work would occur in the existing right-of-way. Tortoise populations are depleted for more than a kilometer on either side of roads having average daily traffic greater than 180 vehicles (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Game species, wild horses and burros, and other animals could temporarily avoid habitat adjacent to roads during highway upgrades, but upgrades would not otherwise add to the effects of these roads on the movement patterns or behavior of these animals. The modification of bridges and culverts over perennial streams, if necessary, could temporarily disrupt stream flow and increase sedimentation in downstream aquatic environments. DOE anticipates that preconstruction surveys of potentially disturbed areas would identify and locate sensitive biological resources and best management practices would minimize the impacts of highway upgrades.

All of the heavy-haul truck implementing alternatives cross perennial or ephemeral streams that may be classified as jurisdictional waters of the Unites States. Discharge of dredged or fill material into those waters is regulated under Section 404 of the Clean Water Act. After the selection of a heavy-haul truck implementing alternative, if requested, DOE would assist the Nevada Department of Transportation to identify any jurisdictional waters of the United States that highway upgrades would affect; develop a plan to avoid when possible, and otherwise minimize, impacts to those waters; and obtain, as appropriate, an individual or regional permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material. By implementing the mitigation plan and complying with other permit requirements, the Nevada Department of Transportation would ensure that impacts to wetlands and other waters of the United States would be small.

The primary soil impacts from improvements to highways would be land disturbance. Road improvements would consist of widening existing roadways, constructing turnouts and truck lanes at designated stretches along the routes, and improving existing intersections. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. Drainage control along the route probably would remain as it is now. These combined measures would minimize the potential for adverse impacts to soils.

Intermodal Transfer Station Construction. The biological settings of the three potential sites for an intermodal transfer station differ; Section 6.3.3.2 addresses impacts for each of the Nevada heavy-haul transportation implementing alternatives.

Soil impacts from the construction of an intermodal transfer station would arise primarily from the direct impacts of land disturbance and would apply to each station site and route. Chapter 3, Section 3.2.2.2.1, lists estimates of land area required for an intermodal transfer station. The disturbed areas probably would be subject to increased erosion for at least some of the construction phase. Water would be applied during construction to suppress dust and compact the soil; this would reduce the potential for erosion. At the beginning of station construction, the topsoil would be stripped and stockpiled; during construction, temporary erosion control systems would minimize erosion impacts. At the completion of construction, the topsoil would be replaced over areas not used for station facilities, the area disturbed surrounding the station would be revegetated, and other permanent erosion control systems would be installed as appropriate.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Impacts to biological resources from operations along any of the five possible routes would be very small. Because existing roadways would not be greatly altered, operations and maintenance would not lead to additional habitat losses. Heavy-haul truck operations could kill individuals of some species, but losses would be unlikely to have a detectable impacts on the regional population of any species and would be small in comparison to losses caused due to other traffic on the highways. Passing trucks could disrupt wildlife, but such effects would be transitory. The use of an upgraded highway would have only a small impact on soils.

Impacts to biological resources from operations at an intermodal transfer station and a midroute stopover would be very small. Operations would not lead to additional habitat losses. Individuals of some species could be disturbed or killed by human activities at the station and stopover, but such losses would be unlikely to have a detectable impact on the regional population of any species.

The use of a completed intermodal transfer station and midroute stopover should have only small impacts on soils. The station and stopover would be maintained throughout the operations period, including the repair of erosion damage to the grounds around the station and the rail siding.

Other impacts to biological resources would differ among the heavy-haul truck implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.6 *Common Route Cultural Resources Impacts*

Highway Construction and Upgrades and Intermodal Transfer Station Construction. Impacts (such as disturbing sites or damaging artifacts) could occur, primarily from surface-disturbing activities, to archaeological, historic, and traditional Native American cultural sites from upgrading highways, constructing a midroute stopover, and building an intermodal transfer station. Cultural resource inventories by the Nevada Department of Transportation and others identify certain archaeological and historic sites in established rights-of-way [generally about 60 meters (200 feet) wide]. Section 6.3.3.2 discusses the impacts of individual routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. After the identification, evaluation, and mitigation of impacts to significant cultural sites prior to construction activities associated with the upgrading of highways or construction of an intermodal transfer station, there would be no additional impacts to these resources from the operation of a heavy-haul truck route.

Although existing highways would be used, American Indians have expressed concern about the transport of spent nuclear fuel and high-level radioactive waste through tribal lands and through the larger region that comprises their traditional holy lands (DIRS 102043-AIWS 1998, all). Use of the Caliente/Las Vegas, Apex/Dry Lake, or Sloan/Jean route would include travel on U.S. 95 across a 1.6-kilometer (1-mile) section of the Las Vegas Paiute Indian Reservation. The Caliente/Las Vegas and Apex/Dry Lake routes pass near the Moapa Indian Reservation. The Caliente route along U.S. Highway 95 runs adjacent to the Scottys Junction trust lands parcel that Congress recently transferred to the Timbisha Shoshone tribe.

Other impacts to cultural resources would differ among the heavy-haul truck implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.7 *Common Route Occupational and Public Health and Safety Impacts*

Highway Construction and Upgrades. Traffic-related fatalities could occur among workers and members of the public during the upgrading of Nevada highways for heavy-haul truck use. The number of fatalities would depend on the amount of construction activity needed to upgrade a route. There would be no other common impacts for highway construction under any of the implementing alternatives. Section 6.3.3.2 describes impacts for each of the implementing alternatives. The construction of a midroute stopover for routes originating in Caliente would not add much to the impacts of highway construction discussed in Section 6.3.3.2.

Intermodal Transfer Station Construction. Impacts to workers from industrial hazards during the construction of an intermodal transfer station would be the same for all three possible locations. These impacts would be small (see Table 6-85). The analysis estimated impacts to workers in terms of total recordable cases of injury or illness, lost workday cases, and fatalities to workers. In addition, it estimated that there would be less than 1 (0.03) construction and construction workforce traffic-related fatality.

Table 6-85. Health impacts to workers from industrial hazards during construction of an intermodal transfer station.

Group	Total recordable cases[a]	Lost workday cases	Fatalities
Involved	3.8	1.8	0.01
Noninvolved[b]	0.3	0.1	0
Totals[c]	4.1	1.9	0.01

a. Total recordable cases includes injuries and illness.
b. Noninvolved worker impacts based on 25 percent of the involved worker level of effort.
c. Impacts are totals for 18 months.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Section 6.3.3.2 discusses impacts for heavy-haul truck transportation and operations for each of the heavy-haul truck implementing alternatives. Common impacts for intermodal transfer station operations would include those to workers from industrial hazards and exposure to ionizing radiation (radiological impacts). DOE has determined that, because worker exposures to hazardous or toxic materials would be unlikely, workers at the station would incur no impacts from such materials. Table 6-86 lists potential impacts to workers from industrial hazards. In addition, there would be less than one (0.38) traffic-related fatality involving intermodal transfer station workers during operations.

Table 6-86. Health impacts to workers from industrial hazards during operation of an intermodal transfer station.

Group	Total recordable cases[a]	Lost workday cases	Fatalities
Involved	52	29	0.14
Noninvolved[b]	3.0	1.1	0.003
Totals[c]	55	30	0.15

a. Total recordable cases includes injuries and illness.
b. Noninvolved worker impacts based on 25 percent of the involved worker level of effort.
c. Totals for 24 years of operations.

Intermodal transfer station workers would be exposed to direct radiation from the shipping casks the station would handle. Involved worker exposures would occur during both the inbound (to the proposed repository) and outbound (to the commercial and DOE sites) portions of the shipment campaign. The involved worker group would include as many as 20 personnel performing station operational tasks over a total shipment campaign of about 19,300 casks (9,650 inbound and 9,650 outbound).

The analysis assumed that noninvolved workers would not be exposed to direct radiation during intermodal transfer station operations. To assess potential radiological impacts at the intermodal transfer stations, the EIS analysis assumed that noninvolved workers would be persons involved with the day-to-day operations of the facility and would have no direct involvement with handling spent nuclear fuel and high-level radioactive waste.

Table 6-87 lists doses and radiological impacts to an individual worker and the involved worker population. The estimated doses are based on involved worker doses from DIRS 104791-DOE (1992, p. 4.2).

Table 6-87. Doses and radiological impacts to involved workers from intermodal transfer station operations.[a]

Group	Dose	Latent cancer fatality
Maximum individual worker	12 rem[b]	0.005[c]
Involved worker population	260 person-rem	0.11[d]

a. Totals for 24 years of operations.
b. Based on 500-millirem-per-year administrative dose limit.
c. The estimated probability of a latent cancer fatality in an exposed individual.
d. The estimated number of latent cancer fatalities in an exposed involved worker population.

Table 6-87 indicates that the involved group of workers could incur a collective dose of about 260 person-rem over the operating period of the intermodal transfer station. The analysis estimated that about 0.1 latent cancer fatality would occur in the exposed worker population. The maximum individual dose accumulated by these workers was assumed to be 500 millirem per year or 12 rem for a worker who worked at the facility for the 24-year operating period. This dose would result in a 0.005 probability of a latent cancer fatality (about a 1-in-200 chance). The assumed annual average dose to an involved worker is the administrative limit on occupational dose that DOE established for its facilities (DIRS 156764-DOE 1999, Article 211). Because vehicles would not be loaded or unloaded at a midroute stopover (Caliente routes), workers at the stopover would receive only small radiation doses.

Incident-Free Transportation. Incident-free impacts of heavy-haul truck transportation in Nevada to individual workers and the public would be unique for each of the five Nevada heavy-haul truck transportation implementing alternatives; these are discussed for each implementing alternative in Section 6.3.3.2. In addition, the incident-free impacts that would occur in Nevada from 1,079 legal-weight truck shipments, although common among the heavy-haul truck implementing alternatives, are reported along with the incident-free impacts for heavy-haul truck transportation in Section 6.3.3.2 for each heavy-haul truck implementing alternative.

Incident-free impacts to hypothetical maximally exposed individuals would be similar among the Nevada heavy-haul truck transportation implementing alternatives. Table 6-88 lists the impacts to maximally exposed individuals including a Nevada-specific individual exposed to heavy-haul truck shipments. Appendix J, Section J.1.3.2.2 describes assumptions for estimating doses to maximally exposed individuals along routes in Nevada.

Accidents. Accident risks and maximum reasonably foreseeable accidents for heavy-haul truck shipments of spent nuclear fuel and high-level radioactive waste would be similar among the Nevada heavy-haul truck transportation implementing alternatives, so this section discusses them.

Table 6-89 lists the accident risks from the transportation of spent nuclear fuel and high-level radioactive waste for the five Nevada heavy-haul truck transportation implementing alternatives. The data show that

Table 6-88. Estimated doses and radiological impacts to a maximally exposed individual for heavy-haul truck implementing alternatives.[a,b]

Individual	Dose (rem)	Probability of latent fatal cancer
Involved workers		
Crew member (rail, heavy-haul truck or legal-weight truck)	48[c]	0.02
Inspector	34	0.013
Railyard crew member	4.2	0.002
Public		
Resident along route (rail)	0.002	0.000001
Nevada resident along route (heavy-haul)[d]	0.53	0.00027
Person in traffic jam[e] (legal-weight truck)	0.02	0.000008
Person at service station[f] (legal-weight truck)	0.08	0.00004
Resident near rail stop[g]	0.002	0.000001

a. The assumed external dose rate is 10 millirem per hour at 2 meters (6.6 feet) from the vehicle for all shipments.
b. Totals for 24 years of operations.
c. Based on 2-rem-per-year administrative dose limit. If a lower dose limit, for example 500 millirem per year, was imposed for transportation workers or state inspectors, maximally exposed individual doses would be lower. See DIRS 156764-DOE (1999, Article 211) for DOE guidance on occupational dose limits.
d. This represents a Nevada resident approximately 15 meters (49 feet) from an intersection. This individual would be exposed for 1 minute per shipment plus 30 minutes per year due to traffic delays.
e. Person in a traffic jam is assumed to be exposed one time only.
f. Assumes the person works at the service station for all 24 years of operations. Mitigation would be required to reduce doses to members of the public to below 100 millirem per year.
g. This represents a Nevada resident approximately 30 meters (98 feet) from the branch rail line. See Section J.1.3.2.2.

Table 6-89. Health impacts[a] to the public from accidents for Nevada heavy-haul truck implementing alternatives.

Risk	Caliente	Caliente/Chalk Mountain	Caliente/Las Vegas	Apex/Dry Lake	Sloan/Jean
Radiological accident risk					
Dose risk (person-rem)	0.01	0.0019	0.056	0.056	0.12
LCF[b]	0.000005	0.000001	0.0000009	0.000028	0.00006
Traffic fatalities	0.6	0.33	0.43	0.23	0.25

a. Impacts are reported for 24 years of operations.
b. LCF = latent cancer fatality.

the risks, which are for 24 years of operations, are low for all five alternatives. These risks include those associated with transporting 1,079 legal-weight truck shipments from the commercial sites that would not have the capability to load rail casks while operational. Small variations in the risk values, principally evident for a Sloan/Jean route, are in part a result of the risks associated with transporting rail casks arriving from the east on the Union Pacific Railroad's mainline through the Las Vegas metropolitan area to a Sloan/Jean intermodal transfer station. The values that would apply for a Caliente/Chalk Mountain or Apex/Dry Lake route are lower because of a shorter route (Apex/Dry Lake), or a more remote and mid-length route (Caliente/Chalk Mountain).

Consequences of Maximum Reasonably Foreseeable Accident Scenarios. DOE evaluated the impacts of maximum reasonably foreseeable accident scenarios for national transportation (see Section 6.2). The results for the national transportation mostly rail scenario apply to transportation in Nevada.

6.3.3.1.8 *Common Route Socioeconomic Impacts*

DOE analyzed five Nevada heavy-haul truck transportation implementing alternatives for potential socioeconomic impacts from expenditures to upgrade and maintain Nevada highways, operate heavy-haul trucks, and construct and operate an intermodal transfer station.

Highway Construction and Upgrades. The dynamics of specific construction projects include a period of brief, intense elevation in project-related employment, followed by an abrupt decrease in associated employment opportunities as construction workers move on to other projects. Project dynamics can also include population increases followed by net declines in population as related employment requirements diminish. In general, increases in population lag behind increases in employment. For the most part, the projected impacts of highway upgrade work would occur in Clark County, which the analysis assumed would be the home county for construction workers because of its large workforce. Section 6.3.3.2 discusses the analysis of impacts to counties along each of the five candidate routes. The time and employment required to complete road upgrades would depend on the route.

Intermodal Transfer Station Construction. If a decision was made to construct an intermodal transfer station, DOE anticipates that preliminary architecture and engineering work would begin in 2007, followed by the start of construction at the selected site in 2008. Construction would last about 18 months. For this analysis, DOE assumed that construction workers would probably come from Clark County.

Although there would be small differences among the three candidate locations for an intermodal transfer station, the total statewide increase in employment (direct and indirect) that would result from the project would peak in 2008 and would be about 135 workers. Population increases resulting from a net influx of new workers would peak in 2009 with about 65 additional residents. These employment and population increases, which would occur mostly in Clark County, would be small and temporary for the affected counties.

Increases in real disposable income from constructing an intermodal transfer station would peak in 2008 at between about $3.6 million and $4.1 million. The increase in Gross Regional Product would also peak in 2008 at between $10.8 million and $11.4 million. State and local government expenditures would peak in 2009 between $198,000 and $243,000. These increases to real disposable income, Gross Regional Product, and government expenditures from construction would be short-term and less than 0.5 percent of the baselines in the affected counties. (All dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Highway Maintenance for Heavy-Haul Truck Operations. If DOE decided to use heavy-haul trucks, annual maintenance would be required after the completion of the highway upgrades. In addition, DOE assumed the routes would be resurfaced approximately every 8 years. Thus, highway expenditures for resurfacing a selected route would occur in approximately 2016, 2024, and 2032. The employment required for road maintenance would depend on the selected route. Section 6.3.3.2 discusses route-specific impacts for each of the five candidate routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The socioeconomic impacts of operating heavy-haul trucks and an intermodal transfer station largely would occur in the county in which the station was located. Section 6.3.3.2 discusses these impacts for each of the five candidate routes.

6.3.3.1.9 *Common Route Noise and Vibration Impacts*

Highway Construction and Upgrades and Intermodal Transfer Station Construction. Impacts would occur from construction noise associated with upgrading road surfaces, constructing a midroute stopover, and constructing an intermodal transfer station. The upgrades and construction would include the use of earth-moving equipment (bulldozers, graders, loaders, dump trucks) and asphalt-laying equipment. Earthmoving equipment would dominate maximum noise levels from construction and would achieve levels of 70 to 80 dBA at 15 meters (50 feet) from the source. The potential for noise impacts from construction would depend on the presence of humans along the routes and near the intermodal transfer station location. These persons would live in communities and possibly individual residences. Noise impacts from road upgrades and general construction would be transient, move with the construction, and end when the construction ended. The impacts, therefore, would be temporary for any location along affected highways. Construction noise, which would not occur at night, would be equivalent to the daytime standard (60 dBA) at distances of about 2,000 meters (6,600 feet). Construction upgrades of heavy-haul truck routes and construction of branch rail lines would be unlikely to cause vibration damage to historic buildings because of the distance of potentially sensitive buildings from construction sites.

The American Indian Writers Subgroup (DIRS 102043-AIWS 1998, p. 2-19) has identified noise generated along transportation routes as a concern because it could affect ceremonies and the solitude necessary for healing and praying. Areas or sites of interest to Native Americans have not been identified along these routes.

Heavy-Haul Truck and Intermodal Transfer Station Operations. Heavy-haul trucks would be double-tractor vehicles that this analysis assumed would travel at speeds of 32 to 80 kilometers (20 to 50 miles) an hour. Noise levels probably would be greatest when loaded heavy-haul trucks were moving up grades at speeds as slow as 8 kilometers (5 miles) an hour. This would occur as the trucks approached the proposed repository site and on portions of the Caliente route (see Chapter 2, Section 2.1.3.3). At 48 kilometers (30 miles) an hour, the estimated noise from a single heavy-haul truck moving up a 5-percent grade would be 45 dBA at a distance of 630 meters (about 2,100 feet) from the road with no background traffic. Elevated truck noise would not be a consideration on the Nevada Test Site, the Nellis Air Force Range, or the repository site. Transportation workers would use hearing protection as required by Occupational Safety and Health Administration regulations.

To assess the impact noise generated by heavy-haul trucks, DOE based the estimated increase in the 1-hour average sound level on traffic volumes along the routes for heavy-haul trucks (DIRS 156930-NDOT 2001, all). Noise estimates were based on a total of three double-tractor vehicles passing through a community or past a given point on a highway within 1 hour (DIRS 155778-Melnick 1998, all). The estimated increase in the 1-hour average sound level would not be perceptible in areas with high traffic volume and would be as high as 0.3 to 4.7 dBA in areas of low traffic volume. The estimated noise levels in this analysis were dominated by commercial tractor-trailers (20 percent of total traffic volume) on the open highway and in smaller communities.

During operations, DOE would transport 11 shipments a week of spent nuclear fuel and high-level radioactive waste to the proposed repository and 11 empty casks from the repository. Because the heavy-haul trucks probably would travel individually, elevated noise would occur during the brief time when a vehicle passed through communities. There would be no nighttime noise because trucks of this size would be restricted to operating during daylight hours. Truck noise at a midroute stopover would be similar to noise along the adjacent route. Therefore, the potential for adverse noise impacts from heavy-haul trucks would be low.

Noise associated with operations at an intermodal transfer station would occur as it received shipments and transferred them from railcars to heavy-haul trucks for transport to the proposed repository site. However, the baseline noise level is already elevated because of existing rail line operations at the potential station locations. Additional sources of noise at a station would include transferring railcars from trains into the station, moving the railcars in the station, and receiving returning empty transportation casks. Railcars could come to the station at night, so there would be a potential for nighttime sources of noise. However, shipments in the station could be handled during daylight hours, minimizing the potential for noise impacts.

Ground vibration resulting from the operation of heavy-haul trucks or trains would be unlikely to produce vibration levels of a magnitude sufficient to cause building damage. Heavy-haul trucks can create potentially damaging vibration if the vehicle hits a bump or pothole in the road. The magnitude of vibration produced depends on the speed of the vehicle and the size of the bump. Most of the energy of impact is absorbed by the inflated tires; as a consequence, ground vibration would not be a major impact for these operations. Heavy-haul trucks would operate at reduced speeds when operated at intermodal transfer stations. There are no known historic buildings or ruins of cultural significance that ground vibration could affect near intermodal transfer stations.

Other noise impacts would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.10 *Common Route Aesthetics Impacts*

Highway Construction and Upgrades and Intermodal Transfer Station Construction. There could be impacts on visual resources during these activities because of the presence of workers, camps, vehicles, large earth-moving equipment, laydown yards, large cranes, and dust generation. However, this phase would be of limited duration (approximately 18 months for an intermodal transfer station and as long as 46 months for highway improvements). An intermodal transfer station would be in an already developed area, either for industrial or commercial use or adjacent to existing roads or rail corridors. Therefore, the facility would not change the character of land use in its vicinity. Dust generation during construction would be controlled by implementing best management practices such as misting or spraying disturbed areas. Construction activities would conform with the Bureau of Land Management Visual Resources Management guidelines (DIRS 101505-BLM 1986, all). If a route crosses Class II lands, more stringent management requirements would be necessary to retain the existing character of the landscape. However, the short duration of highway modification or construction activities, combined with the use of best management practices, would mitigate the impacts of activities, which could exceed the management requirements on any Class II lands.

Heavy-Haul Truck and Intermodal Transfer Station Operations. As many as 22 shipments would leave or arrive at the intermodal transfer station each week. Visual impacts would result from the presence of the station, increased worker activity in the area, the arrival and departure of trains, loading and unloading operations, and the arrival and departure of heavy-haul trucks. Noise and lighting impacts would occur at an intermodal transfer station but, due to the remote locations, there would be no significant impacts. Impacts would not exceed Bureau of Land Management Visual Resource Management Class III objectives, which require only the partial retention of the existing character of the landscape.

Other aesthetic impacts would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.11 *Common Route Utilities, Energy, and Materials Impacts*

Highway Construction and Upgrades. The amounts of utilities, energy, and materials needed would depend on the amount of upgrading to be done, which would be specific to each route. The amount of utilities, energy, and materials for each route is given in the following sections. All of the required amounts are much less than current use rates in Nevada. For example, fossil-fuel consumption in Nevada was about 3.8 billion liters (1 billion gallons) in 1996 and none of the routes would require more than 0.5 percent of the annual consumption (DIRS 148094-BTS 1997, all).

Intermodal Transfer Station Construction. Intermodal transfer station design would be the same for any of the three sites and would include a small railyard with several sidings, a 180-metric-ton (200-ton) bridge crane, two steel prefabricated buildings (one for administration and one for maintenance), and a large paved area for heavy-haul truck parking and maneuvering. The basic facility would be a light industrial site with moderate utility requirements. During construction the electrical requirements would be supplied by portable generating equipment. Table 6-90 lists the materials that would be consumed during construction. The quantities of concrete, asphalt, and steel listed in the table are not substantial in comparison to annual use rates and would not affect the regional supply system. For example, the concrete required for an intermodal transfer station would be less than 1 percent of the concrete used in Nevada in 1998 (DIRS 104926-Bauhaus 1998, all). Similarly, the demand for electricity and fossil fuel during construction would not be great. The construction of a midroute stopover for heavy-haul trucks (routes originating in Caliente) is accounted for in the specific route data included in the following sections.

Table 6-90. Construction utilities, energy, and materials for an intermodal transfer station.

Electrical demand (kilowatts)	Fossil fuel (liters)[a]	Concrete (thousand metric tons)[b]	Asphalt (thousand metric tons)	Steel (thousand metric tons)
Onsite generation	Small	7.9	16	1.4

a. To convert liters to gallons, multiply by 0.26418.
b. To convert metric tons to tons, multiply by 1.1023.

Highway Maintenance for Heavy-Haul Truck Operations. Highways used by heavy-haul trucks would be maintained annually and resurfaced, on average, every 8 years. The amounts of utilities, energy, and materials for the annual and 8-year maintenance activities would be less than the initial amounts for upgrading the highways.

Heavy-Haul Truck and Intermodal Transfer Station Operations. The current estimate of electrical demand during the operation of an intermodal transfer station would be 165 kilowatts (DIRS 155347-CRWMS M&O 1999, Request #38). This would include 30 kilowatts for lighting, 50 kilowatts for each of the two buildings, 5 kilowatts for the guard station, and 30 kilowatts for the crane. The actual rate would be substantially less than peak capacity because operations would be intermittent. Only small amounts of fossil fuel would be used at an intermodal transfer station. Chapter 10 discusses fossil-fuel use for heavy-haul truck operations.

Other impacts on utilities, energy, and materials would differ among the implementing alternatives, as described in Section 6.3.3.2.

6.3.3.1.12 *Common Route Waste Management Impacts*

Highway Construction and Upgrades. Highway construction results in minimal waste. Excavated soil is used for fill elsewhere along the route and asphalt is recycled (DIRS 152538-Hoganson 2000, all; DIRS 152535-Hoganson 2000, all). Upgrading highways, including constructing a midroute stopover with a security trailer, could generate waste such as vegetation from land clearing (DIRS 152538-Hoganson 2000, all), construction debris from the trailer setup, and waste from onsite equipment maintenance (DIRS 152537-Hoganson 2000, all) that an independent contractor would dispose of in permitted landfills, or would recycle in the case of lubricants. In addition, construction materials for upgrading engineered structures such as bridges and culverts would be in correct sizes and numbers to minimize waste. Residual materials would be saved for reuse. A commercial vendor would provide portable restroom facilities and would manage the sanitary sewage. Waste would be handled in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts to vegetation, wildlife, soils, surface and groundwater, and air quality from construction inside or outside of the region of influence.

Intermodal Transfer Station Construction. The administration building would be a prefabricated building and the maintenance building would be built on the site. Construction of the maintenance building would require traditional materials such as steel, lumber, and concrete that would result in debris requiring disposal or recycling. Excess construction materials would be salvaged. A maximum of 23 metric tons (26 tons) of construction debris would be disposed of in a local construction debris landfill. Approximately 750,000 metric tons (820,000 tons) of construction debris was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the maintenance building construction would add less than 0.01 percent. In addition, construction could require paints and resins that could become hazardous if discarded. Hazardous waste would be shipped to a permitted treatment and disposal facility. A commercial vendor would provide portable restroom facilities as necessary and manage the resulting sanitary sewage. Waste quantities from construction would be about the same for all sites. Impacts to treatment and disposal capacity from disposing of the construction debris, hazardous waste, and sanitary sewage would be small and consistent for all station locations.

Highway Maintenance for Heavy-Haul Truck Operations. Periodic maintenance of highways and resurfacing every 8 years would be unlikely to generate wastes, and asphalt would be recycled (DIRS 152535-Hoganson 2000, all). Environmental impacts from waste would be unlikely.

Heavy-Haul Truck Operations. Heavy-haul truck operations along any of the four routes would result in similar wastes from vehicle maintenance. Maintenance wastes are included in the intermodal transfer station operation discussion below.

The operation of a midroute stopover would generate sanitary solid waste and sanitary sewage at the security trailer. The waste would be proportional to the number of persons using the facility, about 5 kilograms (11 pounds) per day per person of solid waste (DIRS 155567-NDEP 2001, p. 5) and about 57 liters (15 gallons) of wastewater per day per person (DIRS 152492-Gibson 1974, p. 55) if potable water is supplied or less if chemical toilets are used. DOE would dispose of the sanitary solid waste in a permitted municipal landfill; the sanitary sewage would be trucked to a municipal sewage facility. The small quantities of solid and sanitary wastes would have a very small impact on treatment and disposal capacity. Management and disposition of the wastes from operations would comply with applicable environmental and occupational and public safety regulations to minimize the possibility of adverse impacts to vegetation, wildlife, air quality, soils, and water resources.

Intermodal Transfer Station Operations. Operations, regardless of the location, would generate (1) sanitary solid waste such as waste paper from office and personnel activities, (2) waste from maintenance activities, and (3) potentially a small amount [0.71 cubic meter (25 cubic feet) per month] of low-level radioactive waste such as the smear wipes from radiological surveys of shipping casks and vehicles (DIRS 104849-CRWMS M&O 1997, p. 10). The routine maintenance and minor repair of the estimated 20 tractor-trailers assigned to an intermodal transfer station would generate waste and recyclable materials. Lubricants, lead-acid batteries, tires, fuel, antifreeze, refrigerant, and miscellaneous used parts would be generated (DIRS 152534-Hoganson 2000, all). The majority of these wastes could be recycled, as is the case at another DOE fleet operation facility (DIRS 152532-Hoganson 2000, all). Estimated annual recyclable material would be 5.5 metric tons (6.0 tons), primarily lubricating oil. Waste requiring disposal would consist of 1,400 kilograms (3,000 pounds) of nonrecyclable tires per year and 23 kilograms (50 pounds) of drained oil filters per year (DIRS 152534-Hoganson 2000, all). About 83,000 metric tons (91,000 tons) of this type of waste was disposed of in Nevada in 2000 (DIRS 155565-NDEP 2001, Section 2.1), so the truck maintenance waste would add less than 0.01 percent. In addition, the intermodal transfer station would generate sanitary sewage that would be disposed of in an onsite septic system or through connection to a municipal sewage facility.

The intermodal transfer station operator would dispose of nonhazardous solid waste in a local permitted landfill with available capacity. Hazardous waste such as nonrecyclable lead-acid batteries and low-level radioactive waste, if any, would be shipped to treatment and disposal facilities with appropriate permits. The small quantities would have very little impact on the treatment and disposal facilities. Treatment and disposal capacity for hazardous waste would be above the expected demand until 2013 (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50). Disposal capacity for a broad range of low-level radioactive wastes would be available at two currently licensed facilities (DIRS 152583-NRC 2000, section on U.S. Low-level Radioactive Waste Disposal).

There would be no unique environmental impacts of waste management for any of the heavy-haul truck implementing alternatives. Waste would be managed in accordance with applicable environmental, occupational safety, and public health and safety requirements to minimize the possibility of adverse impacts to vegetation, wildlife, air quality, soils, and water resources. Impacts to the capacity of treatment and disposal facilities receiving wastes generated during Nevada transportation would be small due to the small quantities of waste expected.

6.3.3.2 Impacts Specific to Individual Nevada Heavy-Haul Truck Implementing Alternatives

6.3.3.2.1 *Caliente Route Implementing Alternative*

The Caliente route (Figure 6-22) is approximately 533 kilometers (331 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the intermodal transfer station to U.S. Highway 93. The trucks would travel west on U.S. 93 to State Route 375, then on State Route 375 to the intersection with U.S. 6. The trucks would travel on U.S. 6 to the intersection with U.S. 95 in Tonopah. The trucks would travel into Beatty on U.S. 95 where a short alternative truck route would be built on the west side of town because an existing intersection is too constricted to allow a heavy-haul truck to turn. Heavy-haul vehicles would then travel south on U.S. 95 to Lathrop Wells Road at Amargosa Valley, which would access the Yucca Mountain site.

DOE would construct a parking area along a Caliente route to enable heavy-haul vehicles to park overnight. This parking area could be needed because the travel time (vehicle in motion plus periodic short stops for inspections) associated with a Caliente route would be as much as 16 hours and because DOE anticipates that the State of Nevada would issue special travel permits for the trucks that would include time-of-day and day-of-the-week travel restrictions that could preclude completing a trip in 1 day. This parking area would probably be near U.S. 6 between Warm Springs and Tonopah.

The potential siting areas for an intermodal transfer station are south of the City of Caliente in the Meadow Valley Wash area. DOE has identified two areas along the west side of the canyon, with a combined area of 0.74 square kilometer (180 acres). Areas along the east side of the canyon would not be used to avoid disrupting Meadow Valley Wash and because of poor access to the Union Pacific rail line. The estimated life-cycle cost to construct and operate an intermodal transfer station and to operate heavy-haul trucks along the Caliente route would be about $669 million in 2001 dollars.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; and utilities, energy, and materials. Impacts that would occur to air quality and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice concerns in Nevada.

6.3.3.2.1.1 Caliente Route Land Use and Ownership

This section describes land-use impacts that could occur from the construction and operation of a Caliente intermodal transfer station and upgrade of highways and heavy-haul truck operation over the

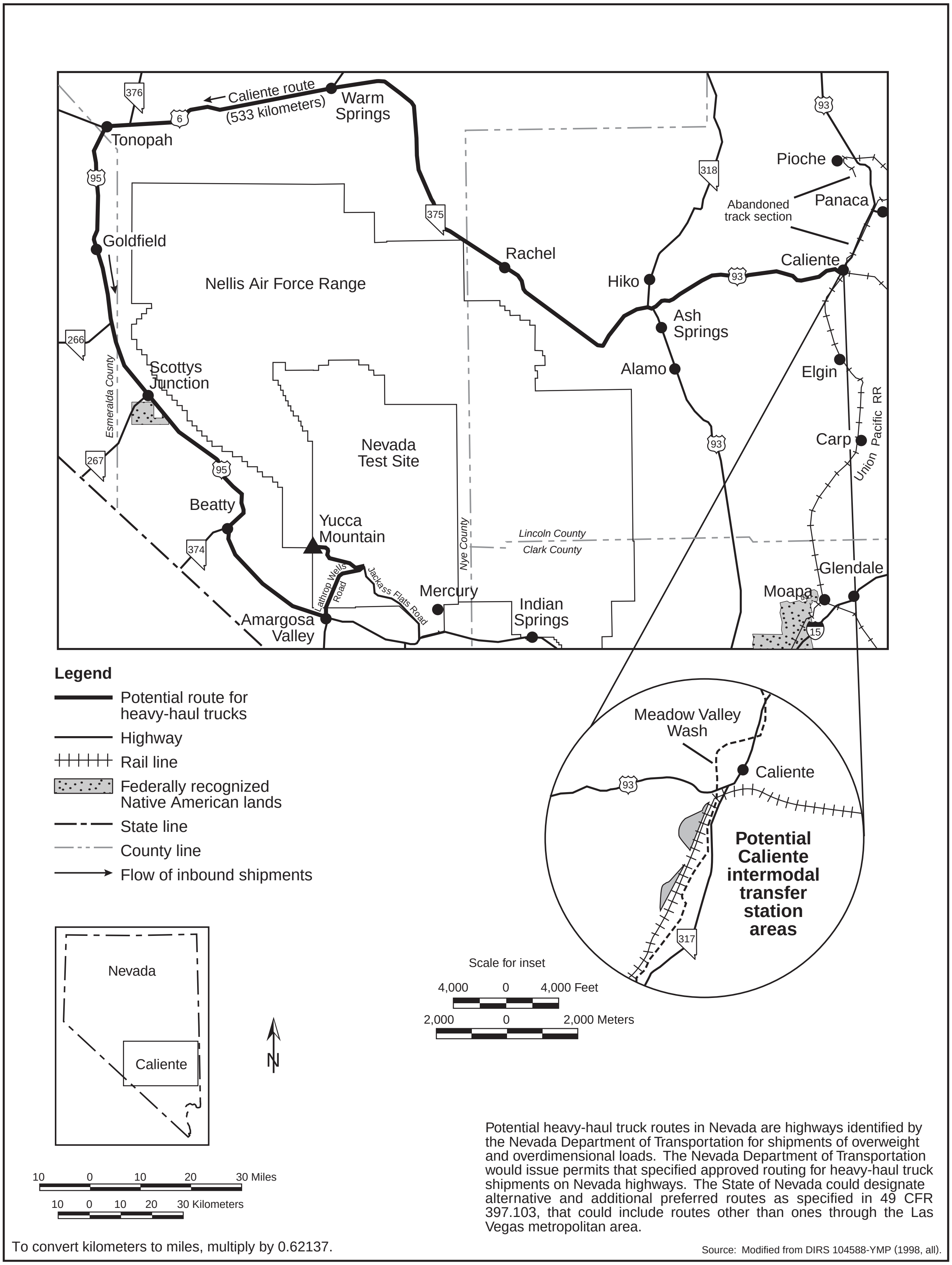


Figure 6-22. Caliente heavy-haul truck route.

Caliente route. Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and associated route.

With the exception of a small portion of the most northern part of the site area for an intermodal transfer station, the area is on patented land owned by the City of Caliente. The remaining part of the northern site is administered by the Bureau of Land Management. The northern site also includes an existing wastewater treatment plant (DIRS 104993-CRWMS M&O 1999, p. 21). A transfer of property from the Bureau, the City of Caliente, or other entities to DOE would be required.

Highway Construction and Upgrades. Land-use impacts that would be common to all locations are discussed in Section 6.3.3.1. The Caliente intermodal transfer station, located near the entrance to Kershaw-Ryan State Park, would be built on lands currently used for industrial or commercial purposes. Because of this, there should be no additional impacts to land use. Park visitors would receive short-term visual impacts from construction activities. In addition, park visitors could be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 3.4 square kilometers (834 acres) of land would be disturbed by the road upgrades and additional construction activities required for this route. Table 6-91 summarizes these disturbances. Approximately 0.04 square kilometer (10 acres) of land near Beatty, Nevada, would be acquired to construct approximately 2 kilometers (1.2 miles) of new highway. This section of highway would be needed to avoid conflicts between the requirement of wide turning areas for heavy-haul trucks and existing land uses in Beatty where U.S. 95 makes a 90-degree turn. In addition, approximately 0.04 square kilometer (10 acres) of land in the vicinity of Tonopah would be acquired for a midroute stopping area for heavy-haul trucks. This additional land requirement could require the purchase by or transfer of land to DOE.

Table 6-91. Land disturbances along the Caliente heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	1.9
Aggregate plants	0.3
Road widening	0.7
Passing lanes	0.2
Truck turnouts	0.08
Beatty truck alternate	0.04
Fortymile Wash new road	0.04
Overnight stops	0.04
Total disturbed area	3.4

. Numbers approximate due to rounding.
. To convert square kilometers to acres, multiply by 247.1.

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or the Caliente route for heavy-haul trucks other than those described in Section 6.3.3.1.

6.3.3.2.1.2 Caliente Route Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these potential impacts as well as those from the construction and operation of an intermodal transfer station and heavy-haul truck operations over the Caliente route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that are unique to the Caliente route.

Surface Water

Section 6.3.3.1 discusses impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed apply to surface water along the Caliente route.

Appendix L contains a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6 and L.4.2.2). As noted in Section L.3.2.6, the two locations being considered for the Caliente intermodal transfer station are outside the 100-year flood zone of Meadow Valley Wash, but inside the 500-year flood zone.

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. The upgrades to the Caliente route would require about 126,000 cubic meters (100 acre-feet) (DIRS 104917-LeFever 1998, all) of water which, for planning purposes, was assumed to come from 16 wells.

The average amount of water withdrawn from each well would be about 7,900 cubic meters (6 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies the hydrographic areas over which the Caliente route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-92 summarizes the status of the hydrographic areas associated with the Caliente route. It also identifies the approximate portion of the route that would pass over Designated Groundwater Basins.

Table 6-92. Hydrographic areas along Caliente route.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
19	8	40

The withdrawal of 7,900 cubic meters (6 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-92, about 40 percent of the route's length would be in areas with Designated Groundwater Basins, where the Nevada State Engineer's office carefully watches the potential for groundwater depletion. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. Requests for water appropriations under this action would be for minor amounts and for a short-term construction action, which should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck to construction sites (about 7,000 truckloads), or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation would ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses the impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

6.3.3.2.1.3 Caliente Route Biological Resources

Section 6.3.3.1 discusses the impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all candidate sites for an intermodal transfer station and associated routes. This section discusses the construction- and operations-related impacts that would be unique to the Caliente intermodal station and route.

Highway Construction and Upgrades. Potential Caliente intermodal transfer station siting locations include two areas along the west side of the Meadow Valley Wash canyon. The land cover types are agriculture and salt desert scrub (DIRS 104593-CRWMS M&O 1999, pp. 3-30 and D-1). The construction site would disturb approximately 0.2 square kilometer (50 acres). No special status species occur in the proposed location of the Caliente intermodal transfer station. However, two species classified as sensitive by the Bureau of Land Management—the Meadow Valley Wash speckled dace and the Meadow Valley Wash desert sucker—occur in the adjacent Meadow Valley Wash (DIRS 104593-CRWMS M&O 1999, p. K-1). The construction of an intermodal transfer station could affect these fish by increasing the sediment load in the wash during construction. This construction would not affect southwestern willow flycatchers or their habitat in Meadow Valley Wash (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). There is no designated game habitat at the proposed location for the intermodal transfer station, but the adjacent Meadow Valley Wash is classified as important habitat for water fowl and Gambel's quail (DIRS 104593-CRWMS M&O 1999, p. 3-30). Impacts to this habitat would be small.

Moist areas in the proposed location and the adjacent perennial stream and riparian habitat along Meadow Valley Wash could be classified as jurisdictional wetlands or other waters of the United States, although no formal wetlands delineation of the area has been conducted. If this site was selected, DOE would delineate the boundaries of any jurisdictional wetlands, develop a plan to mitigate impacts, and consult with the U.S. Army Corps of Engineers regarding the need to obtain a regional or individual permit under Section 404 of the Clean Water Act.

The predominant land cover types along the Caliente route are salt desert scrub, sagebrush, and creosote-bursage (DIRS 104593-CRWMS M&O 1999, p. 3-30). The regional area for each vegetation type is extensive (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way, and have been previously degraded by human activities, impacts would be small. In addition, vegetation would be removed from approximately 0.04 square kilometer (10 acres) of undisturbed land for development of a midroute stopover. This area would be east of the City of Tonopah. The precise location is not known at this time, so the land cover type that would be disturbed cannot be identified. However, as noted above, all land cover types along the route are extensive and often degraded in the region, so loss of this area would be unlikely to cause adverse effects to the population of any plant or animal species.

Three threatened or endangered species occur along the Caliente route (DIRS 104593-CRWMS M&O 1999, p. 3-30). The desert tortoise occurs along the southern part of the route along U.S. 95 from Beatty to Yucca Mountain. Construction activities could kill or injure some tortoises; however, their abundance is low in this area (DIRS 103281-Karl 1981, pp. 76 to 92; DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411), so losses would be small. One endangered species—the Hiko White River springfish—occurs in Crystal Springs (50 CFR 17.95). The outflow of the spring comes within about 10 meters (33 feet) of State Route 375 near its intersection with State Route 318 near U.S. 93 (DIRS 104593-CRWMS M&O 1999, p. 3-30). Therefore, any upgrading of the road in this area could have the potential to affect critical habitat. DOE would ensure that construction activities avoided the spring outflow channel and would implement mitigation measures to ensure that no sediment entered the stream. In addition, formal consultation with the U.S. Fish and Wildlife Service would be initiated if this heavy-haul truck route was selected, and DOE would implement all terms and conditions required by the Service.

An introduced population of the threatened Railroad Valley springfish occurs in Warm Springs (DIRS 103261-FWS 1996, p. 20), the outflow of which crosses U.S. 6. If improvements to the highway in the vicinity of the Warm Springs outflow were necessary, there could be temporary adverse impacts to this introduced population due to habitat disturbance and siltation if not properly mitigated. Six other special status species occur along this route (DIRS 104593-CRWMS M&O 1999, pp. 3-30 and 3-31) but, because construction activities would be limited to the road and adjacent areas and care would be taken to ensure no sediments entered the streams, species should not be affected.

This route would cross eight areas designated as game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-31). The amount of habitat in these areas would be reduced slightly due to construction activities alongside existing roads. Game animals in these areas during construction could be disturbed.

Nineteen springs occur near this route (DIRS 104593-CRWMS M&O 1999, p. 3-31). Areas around these springs may be jurisdictional wetlands or waters of the United States. However, no formal delineation has been made. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and would obtain individual or regional permits, as appropriate.

Impacts on soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along the route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

6.3.3.2.1.4 Caliente Route Cultural Resources

Highway Construction and Upgrades. Previous surveys have recorded a total of 178 archaeological sites within the existing rights-of-ways of the highways that make up this alternative. Upgrade of highways associated with the Caliente heavy-haul truck route would affect (by disturbing the sites or crushing artifacts) two known archaeological sites in the existing highway right-of-way [about 60 meters (200 feet)] that have been evaluated as potentially significant (DIRS 155826-Nickens and Hartwell 2001, p. 12). In addition, another 20 archaeological sites occur in areas in the existing right-of-way that would experience upgrade activities. These sites have been recorded but not evaluated, and include one historic grave along the highway south of Tonopah. This route passes through the southern area of the Tonopah Multiple Resource Area historic mining district and the Goldfield Historic District, both of which are listed on the *National Register of Historic Places*. At Tonopah, the historic district lies north of the junction of U.S. Highways 6 and 95, and heavy-haul truck traffic would not affect the historic components of this district. Although U.S. 95 passes through the heart of the historic district at Goldfield, which includes commercial and private residence buildings in the downtown area, adverse effects from heavy-haul traffic would be unlikely. Two listed historic properties are located in downtown Caliente, near the highways leading from the Caliente intermodal transfer station site. Both of these, the State-listed Smith Hotel and the National Register-listed Union Pacific Depot, are far enough from the highway route that potential impacts are unlikely.

Preliminary studies have identified several areas important to Native Americans along the Caliente heavy-haul truck route that would require additional field ethnographic studies (DIRS 155826-Nickens and Hartwell 2001, Table 8). These include Oak Springs Summit and Six-Mile Flat/Pahroc Summit along U.S. 93 west of Caliente; Crystal Springs, at the junction of U.S. 93 and State Route 375; Twin Springs, Twin Springs slough, and Echo Lakes area, along State Route 375 between Rachel and Warm Springs; and the Warm Springs/Hot Creek Valley area, at the junction of State Route 375 and U.S. 6.

Archaeological surveys at the candidate Caliente intermodal transfer station site just south of the City of Caliente recorded four sites, none of which has been evaluated for eligibility to the *National Register of Historic Places.* Native Americans are familiar with some of these sites, which include a series of painted and pecked rock art, along the cliff immediately west of the candidate intermodal transfer station site (DIRS 155826-Nickens and Hartwell 2001, Table 8). The rock art is adjacent to the flat area where DOE could construct an intermodal transfer station. Although direct impacts to the site would be unlikely, indirect impacts are a possibility. Native Americans would view the presence of an intermodal transfer station near a traditional site as an impact to their cultural values.

Operations. The use of existing highways for heavy-haul truck transport of spent nuclear fuel and high-level radioactive waste would be unlikely to affect historic buildings listed in the National Register district in the Town of Goldfield. Transport of these materials could affect Native American feelings for the potentially significant cultural areas identified along the highways.

The operation of a Caliente intermodal transfer station could have a lasting impact on the cultural integrity of the location, which Native Americans have identified as an important place.

6.3.3.2.1.5 Caliente Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente route. Impacts of the associated intermodal transfer station are the same for each heavy-haul truck implementing alternative and are in Section 6.3.3.1.

Highway Construction and Upgrades. Industrial safety impacts on workers from the upgrade of highways and use of the Caliente route would be small (see Table 6-93). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities due to commuting workers and transporting construction materials and equipment. Table 6-94 lists the estimated fatalities from construction vehicle and commuter traffic.

Table 6-93. Impacts to workers from industrial hazards during the Caliente route construction upgrades.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	66	220
Lost workday cases	33	120
Fatalities	0.09	0.61
Noninvolved workers[d]		
Total recordable cases	4.0	13
Lost workday cases	1.5	4.7
Fatalities	0.004	0.01
Totals[e]		
Total recordable cases	70	240
Lost workday cases	34	127
Fatalities	0.1	0.6

a. Impacts are totals for about 35 months.
b. Includes impacts from periodic resurfacing and maintenance; impacts are totals for 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Operations. The incident-free radiological impacts listed in Table 6-95 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste using the Caliente route. These impacts include transportation along the highway route as well as transportation along railways in Nevada to the Caliente intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-94. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente route for heavy-haul trucks.[a]

Activity	Kilometers[b]	Traffic fatalities	Vehicle emissions fatalities
Construction[c]			
Material delivery vehicles	60,000,000	1.0	0.12
Commuting workers	50,000,000	0.5	0.07
Subtotals[d]	*110,000,000*	*1.5*	*0.19*
Operations[e]			
Commuting workers	200,000,000	2.0	0.26
Totals	***310,000,000***	***3.5***	***0.45***

a. Includes impacts from the construction and operation of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impact totals are for about 35 months.
d. Totals might differ from sums of values due to rounding.
e. Impact totals are for 24 years.

Table 6-95. Health impacts from incident-free Nevada transportation for the Caliente route implementing alternative.[a]

Category	Legal-weight truck shipments[b]	Rail and heavy-haul truck shipments[c]	Totals[d]
Involved workers			
Collective dose (person-rem)	38	1,600	1,600
Estimated latent cancer fatalities	0.02	0.64	0.66
Public			
Collective dose (person-rem)	7	70	77
Estimated latent cancer fatalities	0.003	0.04	0.04
Estimated vehicle emission-related fatalities	0.0016	0.015	0.016

a. Impacts are totals for 24 years.
b. Impacts of 1,079 legal-weight truck shipments from six commercial sites.
c. Includes impacts to workers at an intermodal transfer station and impacts to escorts.
d. Totals might differ from sums of values due to rounding.

6.3.3.2.1.6 Caliente Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways on the Caliente route and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes impacts from the operation of an intermodal transfer station at the Caliente site and periodic resurfacing of highways.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading highways for a Caliente route and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Upgrading the roads for the route would cost about $125 million, and would require about 653,000 worker hours and 35 months to complete. Constructing an intermodal transfer station would cost $25 million and require approximately 18 months to complete. (Dollar values reported in this section are 2001 dollars unless stated otherwise.)

Employment. In the region of influence, increased employment of construction workers involved with upgrading highways or with building an intermodal transfer station (direct workers) and other workers employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008 at about 856 workers. The increase in employment in Clark County would be about 748 workers; Nye and Lincoln Counties would each gain 54. The increases in Clark and Nye Counties would be less than 1 percent of the employment baseline for each county. The increase in Lincoln County employment would be 2.2 percent of the county's employment baseline.

In the three-county region of influence, employment of Caliente route construction workers and of indirect workers would decrease by 738 jobs when the construction of an intermodal transfer station and highway upgrades ended in 2009. At the completion of the construction phase, Clark County would lose 720 of these jobs, Nye County would lose 6, and Lincoln County would lose 12. The impacts would be less than 1 percent of the baselines in Clark and Nye Counties. DOE anticipates that project-related workers would be absorbed in other work in Nevada. Employment projections for the State estimate 1.4 million jobs in 2010.

Population. Projected population increases in the region of influence as a consequence of upgrading highways and constructing an intermodal transfer station for the Caliente route would peak in 2009. During that year, the incremental increase in population would be about 688 individuals. Ninety-one percent (627) of these individuals would live in Clark County, 42 in Nye County, and 18 in Lincoln County. Population changes for Clark, Lincoln, and Nye Counties that would arise from increased employment opportunities would be less than 1 percent of each county's population baseline. Because the increases in each county could be small and transient, impacts to schools or housing would be unlikely.

Economic Measures. Economic measures would rise during the construction of an intermodal transfer station and upgrading of highways, and would decline at the project's end. The temporary change in real disposable income of people in the three-county region of influence would peak in 2008 at $26.5 million. The region-wide change in Gross Regional Product would peak in 2008 at $45.3 million. Increased State and local government expenditures resulting from activities to upgrade highways and construct an intermodal transfer station would peak in 2009 at $2.3 million. The Gross Regional Product, real disposable income, and expenditures by local and State governments would be less than 1 percent higher than the baseline for Clark and Nye Counties. Lincoln County would experience a less-than-1-percent increase in real disposable income and government spending. The increase in Gross Regional Product ($1.4 million) would be 1.2 percent of the county's baseline. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Caliente heavy-haul truck route workers and indirect (support) workers would decrease by 738 when construction of the intermodal transfer station and highway upgrades ended in 2009. Clark County would lose 721 (98 percent) of these jobs. Nye County would lose 5 jobs, and Lincoln County would lose 12 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Caliente route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and continue until 2033. An annual operations workforce of about 26 would be required for an intermodal transfer station, which would operate throughout the year. The direct workforce for heavy-haul truck operations over a Caliente route, including shipment escorts, would be about 120 workers. The analysis assumed that operations workers would reside in Clark, Lincoln, or Nye Counties.

Employment. Employment probably would remain relatively level throughout the operations period. Total employment (direct and indirect) in the region of influence associated with heavy-haul truck transportation and an intermodal transfer station would average about 274 workers. The baseline employment in the region of influence in the 24-year operations period would be about 1.1 million. Firms in the region of influence would employ about 94 percent of these workers. Clark County would gain 111 workers. Nye County would gain 74, and Lincoln County would gain 88. The increases in Clark and Nye Counties would be less than 1 percent of the respective baselines. The increase in Lincoln County would represent 3.3 percent of the county's employment baseline.

Because of the periodic need to resurface highways used by heavy-haul trucks (every 8 years starting in 2016), employment would increase in the years these projects occurred. For these projects, employment (direct and indirect) in the region would increase by about 250 workers. Employment changes from periodic highway-resurfacing projects would be less than 1 percent of the baseline in Clark County. DOE assumed that Clark County-based firms would employ the resurfacing project workers. DOE included the employees who would resurface the roads and their families in the employment and population estimates discussed above for the operations period. Overall impacts to employment and population as a result of highway maintenance and shipment operations would be less than 1 percent of the baselines in each county.

Population. The average annual increase in population in the region of influence as a result of employment associated with a Caliente heavy-haul truck route would be about 638 persons. DOE estimates that about 387 of these would reside in Clark County, about 134 in Nye County, and 117 in Lincoln County. Population increases for Lincoln County, which would experience the largest change as a percentage of the baseline, would be about 2.4 percent.

The change in population in Lincoln County would include an average annual increase of approximately 27 school-aged children. The impact to housing in the county would be negligible given the county's historically high housing vacancy rates (see Chapter 3, Section 3.1.7.4). Impacts attributable to the operation of the Caliente heavy-haul truck route would be within the range of historic changes in the county.

Economic Measures. In the region of influence, real disposable income from the operation of an intermodal transfer station in Caliente, operation of heavy-haul trucks based in Caliente, and periodic resurfacing of the roads would rise during operations, starting at $4.1 million in 2010 and rising to $22 million in 2033. The average annual impact in real disposable income would be $12.9 million. Gross Regional Product would also rise during operations, increasing to $29 million in 2033 and averaging $15.3 million. Annual State and local government expenditures attributable to this heavy-haul truck implementing alternative would increase from $2.2 million in 2010 to $4.0 million in 2033, with an annual average of $2.9 million. The impact of changes in the economic measures of Gross Regional Product, real disposable income, and expenditures by State and local governments would be less than 1 percent for Clark and Nye Counties. The impact in Lincoln County would be more visible. Changes in real disposable income would average 2.4 percent of the baseline, the impact in Gross Regional Product would average 3.7 percent of the baseline, and the change in expenditures by State and local governments would average 2.9 percent of the baseline in the county.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent during construction and by about 8.7 percent during operations. Employment would rise by about 11 percent during construction and about 12 percent during operations.

6.3.3.2.1.7 Caliente Route Noise and Vibration

Section 6.3.3.1 discusses the noise impacts common to all heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Caliente heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The Caliente intermodal transfer station would border a wastewater-treatment facility consisting of drain fields and ponds. There is a single dwelling about 500 meters (1,600 feet) to the northeast of a 0.26-square kilometer (64-acre) parcel that has been identified as a potential site for the Caliente intermodal transfer station. However, this residence is behind a small rise and would be partially shielded from operations at an intermodal transfer station. As a consequence, the potential for noise impacts from construction and operations would be very low at this location.

Operations. Existing traffic on the candidate routes for heavy-haul trucks includes a significant component of tractor-trailer vehicles. Because the intermodal transfer station would be on the western edge of Caliente, traffic to and from the station would not travel through town. Traffic noise impacts in Caliente would be inconsequential. The increase in 1-hour average noise levels would be greatest near Rachel, where traffic volumes are lowest. The estimated elevation of background traffic noise would be 4.7 dBA 15 meters (49 feet) from the road. The estimated baseline traffic noise level of 59.2 dBA would increase to 63.9 dBA when heavy-haul trucks passed Rachel. Estimated traffic noise levels in Tonopah, Goldfield, and Beatty would increase by 0.3 to 2.0 dBA. These small increases in noise levels would not be discernable when compared to existing background levels of current tractor-trailer noise in these communities. Heavy-haul trucks would add only a small increment to the existing baseline noise level associated with traffic on these routes. U.S. 95 is a major transportation corridor for the trucking industry from central California to Las Vegas. U.S. 6, State Route 373 and U.S. 93 (from Crystal Springs to Caliente) carry less traffic than U.S. 95. Ground vibrations would not affect any historic buildings because of the low speeds that heavy-haul trucks would use when passing through Goldfield. No sensitive ruins of cultural significance have been identified along this route.

The Caliente route passes the northeastern border of the Timbisha Shoshone Trust Lands parcel on U.S. 95. Estimated mean 1-hour increases in traffic noise due to heavy-haul trucks in this area would be 0.8 dBA over existing background traffic noise (DIRS 155825-Poston 2001, all). This level of increase would not cause adverse impacts.

6.3.3.2.1.8 Caliente Route Aesthetics

A Caliente intermodal transfer station would be located near the entrance to Kershaw-Ryan State Park. In addition, park visitors would receive short-term visual impacts from construction activities. Park visitors could also be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

During operation of the intermodal transfer station, noise and lighting probably would be discernible from Kershaw-Ryan State Park, especially during night operations, and would probably detract from the recreational experience. The use of shielded and directional-lighting would limit the amount of viewable light from outside the facility operational area.

6.3.3.2.1.9 Caliente Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses the utilities, energy, and materials impacts that would be common to the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Caliente heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Caliente intermodal transfer station would have the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-96 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Caliente route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-96. Utilities, energy, and materials required for upgrades along the Caliente route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente	533	13	220	1.4	1.8	49.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and material needs for operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.2 *Caliente/Chalk Mountain Route Implementing Alternative*

The Caliente/Chalk Mountain route (Figure 6-23) is approximately 282 kilometers (175 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel on U.S. 93 to State Route 375, then on State Route 375 to the Town of Rachel. Next they would head south on Valley Road through the Nellis Air Force Range past Chalk Mountain to the Groom Pass Gate to the Nevada Test Site.

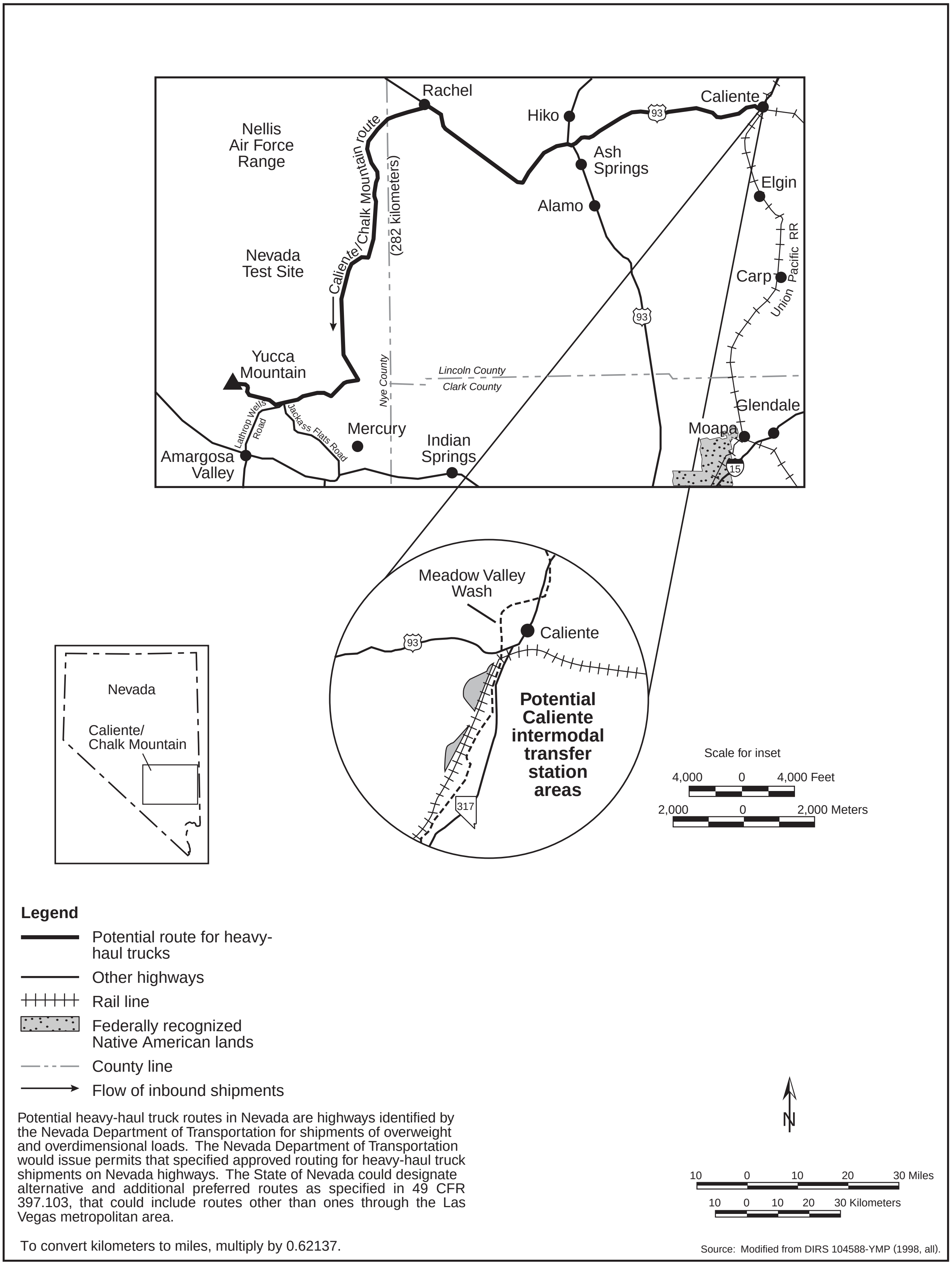


Figure 6-23. Caliente/Chalk Mountain heavy-haul truck route.

DOE would construct a parking area along a Caliente/Chalk Mountain route near the northern boundary of the Nellis Air Force Range to enable heavy-haul vehicles to park overnight. This parking area could be needed because the travel time (vehicle in motion plus periodic short stops for inspections) associated with a Caliente/Chalk Mountain route would be as much as 8 hours and because (1) DOE anticipates restrictions on the times trucks could travel across the Nellis Air Force Range and (2) special travel permits issued by the State of Nevada for the trucks would include time-of-day and day-of-the-week travel restrictions. The estimated life-cycle cost to construct and operate an intermodal transfer station and to operate heavy-haul trucks along the Caliente/Chalk Mountain route would be about $548 million in 2001 dollars.

Section 6.3.3.2.1 discusses the Caliente siting areas for an intermodal transfer station.

The following sections address impacts that would occur to land use; biological resources and soils; cultural resources; hydrology including surface water and groundwater; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics and utilities, energy, and materials. Impacts that would occur to air quality, and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.2.1 Caliente/Chalk Mountain Route Land Use and Ownership

This section describes anticipated land-use impacts that could occur from the construction and operation of the Caliente intermodal transfer station, upgrades of highways, and heavy-haul truck operations over the Caliente/Chalk Mountain route. Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and the associated route to the Yucca Mountain site.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses Caliente intermodal transfer station impacts in relation to the current use of the land and the surrounding area. Section 6.3.3.1 describes impacts on land use from upgrading highways for use by heavy-haul trucks.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 1.3 square kilometers (310 acres) of land would be disturbed by the road upgrades and additional construction activities required for this route. Table 6-97 summarizes these disturbances. Approximately 0.04 square kilometer (10 acres) of land in the vicinity of the northern boundary of the Nellis Air Force Range would be acquired for a midroute stopping area for heavy-haul trucks.

Table 6-97. Land disturbances along the Caliente/Chalk Mountain heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	0.6
Aggregate plants	0.1
Road widening	0.3
Passing lanes	0.1
Truck turnouts	0.02
Fortymile Wash new road	0.04
Overnight stops	0.04
Total disturbed area	1.3

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

The Caliente/Chalk Mountain route would involve land controlled by the Nellis Air Force Range (also known as the Nevada Test and Training Range), which, according to the Air Force, would affect Air Force operations. Because the Military Lands Withdrawal Act of 1999 (Public Law 106-65, 113 Stat. 885) withdraws and reserves the Nellis Air Force Range for use by the Secretary of the Air Force, the Secretary would need to concur with a decision to operate a heavy-haul truck route through any part of the Range. The Air Force has identified national security issues regarding a Caliente/Chalk Mountain route, citing interference with Nellis Air Force Range testing and training activities. In response to Air Force concerns, DOE has stated that it is acutely conscious of the security issues such a route would present and, because of the concerns expressed by the Air Force, regards the route as a "non-preferred alternative."

Operations. The Air Force has identified national security issues regarding operations of heavy-haul trucks on the Caliente/Chalk Mountain route, citing interference with Nellis Air Force Range testing and training activities. There would be no other direct land-use impacts associated with the operation of the Caliente intermodal transfer station or the Caliente/Chalk Mountain route except those described above and in Section 6.3.3.1.

6.3.3.2.2.2 Caliente/Chalk Mountain Route Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so that they could accommodate daily use by heavy-haul trucks. This section discusses these potential environmental impacts as well as those from the construction and operation of an intermodal transfer station and operation of the Caliente/Chalk Mountain route. Section 6.3.3.1 discusses the hydrological impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Caliente/Chalk Mountain route.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways.

Appendix L contains a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6 and L.4.2.2). As noted in Section L.3.2.6, the two locations being considered for the Caliente intermodal transfer station are outside the 100-year flood zone of Meadow Valley Wash, but inside the 500-year flood zone.

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. Upgrades to the Caliente/Chalk Mountain route would require about 75,000 cubic meters (60 acre-feet) of water (DIRS 104917-LeFever 1998, all) that the analysis assumed would come from five wells.

The average amount of water withdrawn from each well would be about 15,000 cubic meters (12 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies hydrographic areas over which the Caliente/Chalk Mountain route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-98 summarizes the status of the hydrographic areas associated with the Caliente/Chalk Mountain heavy-haul truck route. It also identifies the approximate percentage of the route that would pass over Designated Groundwater Basins.

Table 6-98. Hydrographic areas along Caliente-Chalk Mountain route.

	Designated Groundwater Basins	
Hydrographic areas	Number	Percent of corridor length
10	2	20

The withdrawal of 15,000 cubic meters (12 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente/Chalk Mountain route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-98, about 20 percent of the route's length would be in areas with Designated Groundwater Basins, which the Nevada State Engineer's office watches carefully for the potential for groundwater depletion. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. The fact that requests for water appropriations under this action would be for minor amounts and for a short-term construction action should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (4,000 truckloads) to construction sites, or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses the impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

6.3.3.2.2.3 Caliente/Chalk Mountain Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all candidate sites for an intermodal transfer station and routes. This section discusses the construction- and operations-related impacts that would be unique to the Caliente intermodal station and Caliente/Chalk Mountain route.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses potential Caliente intermodal transfer station site locations and impacts to biological resources from station construction.

The predominant land cover types along the Caliente/Chalk Mountain route are salt desert scrub, blackbrush, sagebrush, and creosote-bursage (DIRS 104593-CRWMS M&O 1999, p. 3-31). The regional area for each vegetation type is extensive (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5). Because areas disturbed by highway upgrade activities would be in or adjacent to existing rights-of-way, and because these areas have been previously degraded by human activities, impacts would be small. In addition, vegetation would be removed from approximately 0.04 square kilometer (10 acres) of undisturbed land for development of a midroute stopover. This area would be near or outside the boundary of Nellis Air Force Range. The precise location is not known at this time, so the land cover type that would be disturbed cannot be identified. However, as noted above, all land cover types along the route are extensive and often degraded in the region, so the loss of this area would be unlikely to cause adverse effects to the population of any plant or animal species.

Two threatened or endangered species occur along the route (DIRS 104593-CRWMS M&O 1999, p. 3-32). The desert tortoise occurs along the southern part of the route from the northern end of Frenchman Flat to Yucca Mountain. Construction activities could kill or injure desert tortoises; however, their abundance is low in this area (DIRS 101914-Rautenstrauch and O'Farrell 1998, pp. 407 to 411), so losses would be few. One endangered species—the Hiko White River springfish—occurs in Crystal Springs (DIRS 103262-FWS 1998, p. 16), which is about 10 meters (33 feet) south of State Route 375 near its intersection with State Route 318 near U.S. 93. Construction or widening of the road would be unlikely to affect this species because construction activities would avoid the spring outflow channel, and DOE would implement mitigation measures to ensure that no sediment would enter the stream, which is critical habitat for this fish (50 CFR 17.95). Three other special status species occur along this route, but because construction activities would occur along existing roads, they should not be affected. Standard construction practices would be used to reduce erosion and runoff. In addition, formal consultation with the U.S. Fish and Wildlife Service would be initiated if this heavy-haul truck route was selected, and DOE would implement all terms and conditions required by the Service.

This route would cross six areas designated as game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-32). The amount of habitat in these areas would be reduced very slightly due to construction activities along existing roads. Game animals could be disturbed if they were in these areas during construction.

Three springs or riparian areas occur near this route (DIRS 104593-CRWMS M&O 1999, p. 3-32). These springs and riparian areas may be jurisdictional wetlands or other waters of the United States; however, no formal delineation has been made. DOE would implement mitigation measures to ensure that construction would not increase sedimentation in these areas. The route crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas and would obtain individual or regional permits, as appropriate.

Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

6.3.3.2.2.4 Caliente/Chalk Mountain Route Cultural Resources

Highway Construction and Upgrades. Upgrades to U.S. 93 and State Route 375 would create similar impacts (such as disturbing sites or crushing artifacts) for archaeological, historic, and Native American resources as those identified with the use of the Caliente heavy-haul truck route. Potential impacts at the Caliente intermodal transfer station would also be the same.

Surveys have recorded 31 archaeological sites, five of which have been evaluated as being potentially significant. One is a historic mining camp that has not been evaluated. Additional field surveys would be necessary to record and evaluate cultural resource sites along the route segment from State Route 375 to Yucca Mountain, along with field ethnographic studies. Within the Nevada Test Site, the National Register-listed historic property of Sedan Crater would be located close to, but at a presently unspecified distance, from the proposed new route heavy-haul segment. If this route is selected, final engineering of the alignment would determine if there would be any potential impacts to this historic property.

Table 6-99. Impacts to workers from industrial hazards from upgrading highways along the Caliente/Chalk Mountain route.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	35	220
Lost workday cases	17	120
Fatalities	0.05	0.61
Noninvolved workers		
Total recordable cases	2.1	13
Lost workday cases	0.8	4.7
Fatalities	0.002	0.01
otals[d]		
Total recordable cases	37	240
Lost workday cases	18	130
Fatalities	0.05	0.62

a. Impacts are totals over about 2 years.
b. Includes impacts from periodic maintenance and resurfacing. Impacts are totals over 24 years.
c. Total recordable cases includes injury and illness.
d. Totals might differ from sums due to rounding.

Operations. Impacts from the use of the Caliente/ Chalk Mountain route from the Caliente intermodal transfer station to the point at which it leaves State Route 375 would be the same as those identified for the Caliente route in Section 6.3.3.2.1.

6.3.3.2.2.5 Caliente/Chalk Mountain Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente/Chalk Mountain route. Impacts of the associated intermodal transfer station in Caliente would be the same as those discussed in Section 6.3.3.1.

Highway Construction and Upgrades. Industrial safety impacts to workers from upgrading highways for the Caliente/Chalk Mountain route would be small (Table 6-99). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-100 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-100. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente/Chalk Mountain route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	18,000,000	0.3	0.04
Commuting workers	30,000,000	0.3	0.04
Subtotals	*48,000,000*	*0.6*	*0.08*
Operations[c]			
Commuting workers	180,000,000	1.8	0.24
Totals[d]	***230,000,000***	***2.4***	***0.32***

a. To convert kilometers to miles, multiply by 0.62137.
b. Impacts are totals over about 2 years.
c. Impacts are totals over about 24 years.
d. Totals might differ from sums of values due to rounding.

Operations. The incident-free radiological impacts listed in Table 6-101 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste using the Caliente/Chalk Mountain route. These impacts include transportation along the route and along railways in Nevada leading to an intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-101. Impacts from incident-free transportation for the Caliente/Chalk Mountain heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	38	1,200	1,200
Estimated latent cancer fatalities	0.02	0.48	0.5
Public			
Collective dose (person-rem)	7	60	70
Estimated latent cancer fatalities	0.003	0.03	0.03
Estimated vehicle emission-related fatalities	0.0016	0.0063	0.0079

a. Impacts are totals for 24 years.
b. Includes impacts to workers at an intermodal transfer station and impacts to escorts.
c. Totals might differ from sums of values due to rounding.

6.3.3.2.2.6 Caliente/Chalk Mountain Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along the Caliente/Chalk Mountain route and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes the impacts from the operation of an intermodal transfer station at Caliente and periodic resurfacing of the highways.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading public highways, roads on the Nellis Air Force Range, and roads on the Nevada Test Site for a Caliente/Chalk Mountain route and for building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Employment for highway upgrades and intermodal transfer station construction would involve workers laboring for about 241,000 worker hours. Upgrading the highways along this route would cost about $65.6 million and would require 26 months to complete.

Constructing an intermodal transfer station would cost $25 million and require 18 months. (Dollar values reported in this section are 2001 dollars unless otherwise stated.)

Employment

In the region of influence, increased employment of construction workers involved with upgrading the highways or with building an intermodal transfer station (direct workers) and of other workers employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008 at about 751 new jobs. The increase in employment for Clark County would be about 650 workers and Nye County would gain 44 workers. These increases represent less than 1 percent of each county's employment baseline. For Lincoln County, the increase in employment would be as much as 57 workers or 2.3 percent of the employment baseline. Changes in Lincoln County would be primarily the result of indirect employment created by the spending of construction workers.

Population

Changes in population in the region of influence as a consequence of construction work would peak in 2009. During that year, the incremental increase in population would be about 463 individuals. Clark County would experience 91 percent of the change. Population changes for Clark, Lincoln, and Nye Counties from increased employment would be less than 1 percent of each county's baseline. Because employment and population impacts arising from highway upgrade and the construction of an intermodal transfer station for the Caliente/Chalk Mountain route projects would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station and upgrading of highways. The increase in real disposable income in the three counties in the region of influence would peak at about $21.8 million in 2009. Gross Regional Product would peak in 2008 at $39.8 million. Increased State and local government expenditures resulting from highway upgrades and the construction of an intermodal transfer station would reach their peak in 2009 at $1.6 million. Changes to government expenditures and real disposable income would be less than 1 percent of the respective baselines for Clark, Lincoln, and Nye Counties. Changes to Gross Regional Product in Clark and Nye Counties would also be less than 1 percent of the baselines. The increase in Gross Regional Product in Lincoln County would be about 1.2 percent of the county's baseline for that economic measure. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Caliente/Chalk Mountain heavy-haul truck route workers and indirect (support) workers would decrease by 677 when construction of the intermodal transfer station and highway upgrades ended in 2009. Clark County would lose 506 (83 percent) of these jobs. Nye County would lose 41 jobs, and Lincoln County would lose 33 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Caliente/Chalk Mountain route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and would continue until 2033. An annual operations workforce of 26 would be required for the intermodal transfer station. The workforce for heavy-haul truck operations over a Caliente/Chalk Mountain route, including shipment escorts, would be 110 workers.

Employment

Employment probably would remain relatively level throughout operations. Total employment (direct and indirect) attributable to the Caliente/Chalk Mountain route in the region of influence would average about 237 jobs. Clark County would supply about 87 of the workers, Nye County about 17, and Lincoln

County about 133. The increase in employment in Clark and Nye Counties would be less than 1 percent of each county's employment baseline. The increase in employment in Lincoln County would represent an impact of 4.9 percent of the county's employment baseline.

Because of the periodic need to resurface highways used by heavy-haul trucks (every 8 years starting in 2016), employment would increase in the years during which these projects occurred. For these projects, total employment in the region of influence would increase by about 100 workers for a Caliente/Chalk Mountain route. Employment changes from periodic highway-resurfacing projects would be less than 1 percent of the baseline in Clark County. DOE assumed that resurfacing project workers would live in Clark County. DOE included the workers employed to resurface the roads and their families in the employment and population estimates for the operations period. Impacts to employment and population for the three counties in the region of influence as a consequence of the resurfacing projects would be less than 1 percent of the baselines.

Population

The impact on population in the region of influence would be approximately 506 additional residents. Clark County would gain 296 residents, Nye County would gain 43, and Lincoln County would gain 167. The impact from a population increase in Clark and Nye Counties would be less than 1 percent of each county's baseline. There would no impacts to housing or schools in Clark and Nye Counties. Population increases for Lincoln County, which would experience the largest change, would be approximately 3.5 percent of the baseline. These impacts to employment and population during the operations phase would be within the range of historic changes in the County.

The population change in Lincoln County would include an average annual increase of approximately 38 school-aged children. The impact to housing attributable to the Caliente/Chalk Mountain heavy-haul route would be negligible given the County's historically high housing vacancy rates (see Chapter 3, Section 3.1.7.4).

Economic Measures

In the region of influence, additional real disposable income from the operation of an intermodal transfer station in Caliente, operation of heavy-haul trucks, and periodic resurfacing of the roads would rise throughout operations, starting at $3.9 million in 2010 and increasing to $15.8 million in 2033. The average annual increment in real disposable income would be $11.1 million. Increments to Gross Regional Product would also rise during operations, starting at $2.4 million in 2010, increasing to $20.4 million in 2033, and averaging $13.7 million. Additional annual State and local government expenditures would increase from $1.6 million in 2010 to $3.8 million in 2033, and would average $2.8 million.   The increases in real disposable income, Gross Regional Product, and expenditures by governments would be less than 1 percent of the applicable baseline in Clark and Nye Counties. Increases to real disposable income, Gross Regional Product, and government expenditures attributable to the Caliente/Chalk Mountain route would be more visible in Lincoln County. Changes in real disposable income and government expenditures for the county would be about 3.3 and 4.2 percent, respectively, of the baselines. The projected change in Gross Regional Product for the County would be 5.1 percent of the baseline.

In addition, DOE analyzed a sensitivity case that assumed all Lincoln County socioeconomic impacts would occur only in the City of Caliente. Under this assumption, City population would rise by 3 percent during construction and by about 8.7 percent during operations. Employment would rise by about 11 percent during construction and about 12 percent during operations.

6.3.3.2.2.7 Caliente/Chalk Mountain Route Noise and Vibration

Section 6.3.3.1 discusses the noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Caliente/Chalk Mountain heavy-haul truck implementing alternative.

Noise impacts of the Caliente intermodal transfer station would be the same as those discussed in Section 6.3.3.2.1. A large portion of the route would be inside the boundaries of the Nevada Test Site and the Nellis Air Force Range. The small rural communities of Crystal Spring and Rachel and the Town of Caliente would be within the 2,000-meter (6,600-foot) region of influence for construction noise.

Existing traffic on the candidate routes for heavy-haul trucks includes a significant component of tractor-trailer vehicles. The increase in 1-hour average noise levels would be greatest near Rachel, where traffic volumes are lowest. The estimated elevation of background traffic noise would be 0.6 dBA 15 meters (49 feet) from the road. The estimated baseline traffic noise level would be 61.4 dBA, which would increase to 62.4 dBA with three heavy-haul trucks passing Rachel. Because the proposed intermodal transfer station would be on the western edge of Caliente and traffic would not travel through town, traffic noise impacts in Caliente would be inconsequential. No historic buildings would be affected by ground vibration.

6.3.3.2.2.8 Caliente/Chalk Mountain Route Aesthetics

A Caliente intermodal transfer station would be near the entrance to Kershaw-Ryan State Park. Park visitors would receive short-term visual impacts from construction activities. In addition, park visitors could be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

During operation of the intermodal transfer station, noise and lighting probably would be discernible from Kershaw-Ryan State Park, especially during night operations, and would probably detract from the recreational experience. The use of shielded and directional lighting would limit the amount of viewable light from outside the facility operational area.

6.3.3.2.2.9 Caliente/Chalk Mountain Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy and materials impacts that would be unique to the Caliente/Chalk Mountain heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Caliente intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-102 lists the estimated quantities of primary materials for the upgrade of highways for the Caliente/Chalk Mountain route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-102. Utilities, energy, and materials required for upgrades along the Caliente/Chalk Mountain route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente-Chalk Mountain	282	4.7	77	0.41	0.5	14

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitment of resources.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

6.3.3.2.3 *Caliente/Las Vegas Route Implementing Alternative*

The Caliente/Las Vegas route (Figure 6-24) is approximately 377 kilometers (234 miles) long. Heavy-haul trucks and escorts leaving an intermodal transfer station in the Caliente area would travel directly from the station to U.S. 93. The trucks would travel south on U.S. 93 to the intersection with I-15 northeast of Las Vegas. The trucks would then travel south on I-15 to the exit for the proposed Las Vegas Beltway, and would travel west on the beltway. They would exit the beltway to U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site.

DOE would construct a parking area along a Caliente/Las Vegas route to enable heavy-haul vehicles to park overnight. This parking area could be needed because the travel time (vehicle in motion plus periodic short stops for inspections) associated with a Caliente/Las Vegas route would be as much as 9 hours and because DOE anticipates (1) requirements to coordinate travel times with time of reduced traffic flow on the northern portion of the Las Vegas Beltway and (2) special travel permits issued by the State of Nevada for the trucks would include time-of-day and day-of-the-week travel restrictions that could preclude completing a trip in 1 day. This parking area would be near the U.S. 93 and I-15 intersection at Apex. The estimated life-cycle cost of constructing and operating an intermodal transfer station and of operating heavy-haul trucks along the Caliente/Las Vegas route would be about $607 million in 2001 dollars.

Section 6.3.3.2.1 discusses the Caliente siting areas for an intermodal transfer station.

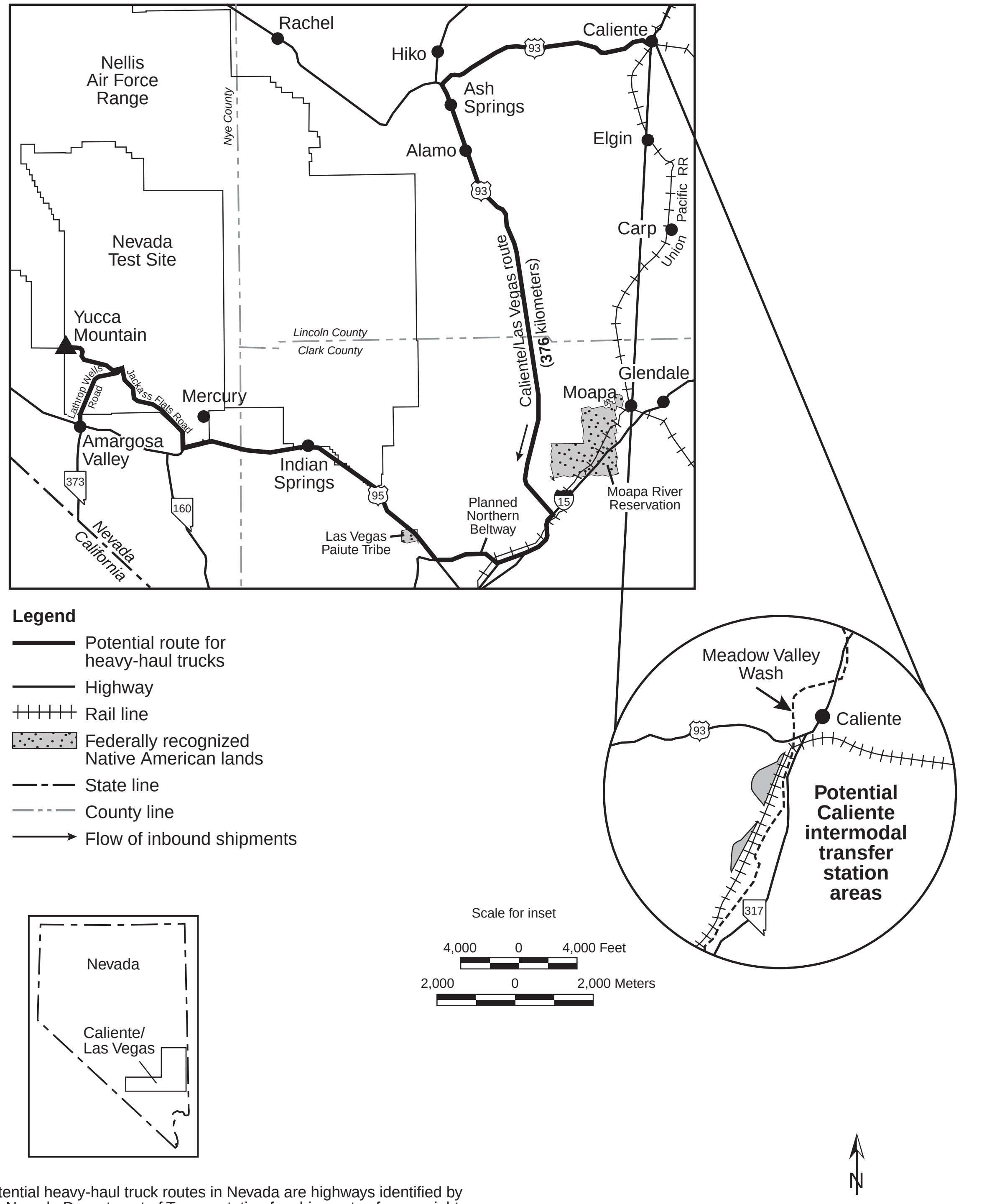
The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; aesthetics; and utilities, energy, and materials. Impacts that would occur to waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.3.1 Caliente/Las Vegas Route Land Use and Ownership

Chapter 3, Section 3.2.2.2.1, describes the Caliente intermodal transfer station site and associated truck route.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses the Caliente intermodal station site area and impacts related to the current use of the land. Section 6.3.3.1.1 discusses the impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

In addition to the impacts on land use discussed in Section 6.3.3.1 for upgrading Nevada highways, approximately 2.1 square kilometers (520 acres) of land would be disturbed by the road upgrades and additional construction activities required. Table 6-103 summarizes these disturbances. Approximately 0.04 square kilometer (10 acres) of land in the vicinity of Apex northeast of Las Vegas would be acquired for a midroute stopping area for heavy-haul trucks.



Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.

To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-24. Caliente/Las Vegas heavy-haul truck route.

Operations. There would be no direct land-use impacts associated with the operation of the Caliente intermodal transfer station or use of the Caliente/Las Vegas route other than those described in Section 6.3.3.1.

6.3.3.2.3.2 Caliente/Las Vegas Route Air Quality

This section describes anticipated nonradiological air quality impacts from the construction and operation of an intermodal transfer station and upgrades and heavy-haul truck operation along the Caliente/Las Vegas route. Such impacts would result from releases of criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}) (see Section 6.3.3.1).

Table 6-103. Land disturbances along the Caliente/Las Vegas heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	1.2
Aggregate plants	0.2
Road widening	0.5
Passing lanes	0.08
Truck turnouts	0.02
Fortymile Wash new road	0.04
Overnight stops	0.04
Mercury turnoff road	0.03
Total disturbed area	2.1

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

Carbon dioxide and PM_{10} are of particular interest along the Caliente/Las Vegas heavy-haul truck route because highway construction and upgrades and operation of heavy-haul trucks would occur through the Las Vegas Valley air basin, which is classified as a serious nonattainment area for these pollutants (DIRS 101826-FHWA 1996, pp. 3-53 and 3-54).

Highway Construction and Upgrades. Section 6.3.3.1 discusses the method of evaluation of air quality impacts from these activities. The intermodal transfer station for this route would be outside the Las Vegas air quality nonattainment area.

PM_{10} emissions would be an estimated 66 metric tons (73 tons) per year, including estimated emissions for accelerated construction activities for the Northern Beltway. These emissions are 100 percent of the General Conformity threshold level. Extending the construction time and more diligent dust control measures would decrease annual emissions.

Carbon monoxide emissions would be an estimated 54 metric tons (59 tons) per year. These emissions are 59 percent of the General Conformity threshold level.

Operations. Section 6.3.3.1 discusses air quality impacts associated with the operation of the Caliente intermodal transfer station and from emissions of heavy-haul trucks. The Caliente/Las Vegas route would involve heavy-haul trucks passing through the Las Vegas Valley air basin. The air quality impacts to this air basin would be small [0.48 metric ton (0.53 ton) per year of carbon monoxide] with emissions of less than 1 percent of the General Conformity threshold level. These emissions would result from 11 round trips per week through the basin.

6.3.3.2.3.3 Caliente/Las Vegas Route Hydrology

DOE anticipates that limited impacts to surface water and groundwater would occur in the course of improving Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these potential impacts as well as those from the construction and operation of an intermodal transfer station and operation of the Caliente/Las Vegas route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Caliente/Las Vegas heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed would apply to surface water along the Caliente/Las Vegas route.

Appendix L contains a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.6 and L.4.2.2). As noted in Section L.3.2.6, the two locations being considered for the Caliente intermodal transfer station are outside the 100-year flood zone of Meadow Valley Wash, but inside the 500-year flood zone.

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses impacts to groundwater from the construction of an intermodal transfer station. Groundwater impacts from upgrading highways would be limited to those caused by the use of water from construction wells. The upgrades to the Caliente/Las Vegas route would require about 54,000 cubic meters (44 acre-feet) of water (DIRS 104917-LeFever 1998, all) that the analysis assumed would come from seven wells.

Table 6-104. Hydrographic areas along Caliente/Las Vegas route.

	Designated Groundwater Basins	
Hydrographic areas crossed	Number	Percent corridor length represented
13	5	50

The average amount of water withdrawn from each well would be about 7,700 cubic meters (6 acre-feet). Chapter 3, Section 3.2.2.2.3, identifies the hydrographic areas over which the Caliente/Las Vegas route would pass, their perennial yields, and whether the State considers each a Designated Groundwater Basin. Table 6-104 summarizes the status of the hydrographic areas associated with the Caliente/Las Vegas route and identifies the approximate portion of the route that would pass over Designated Groundwater Basins.

The withdrawal of 7,700 cubic meters (6 acre-feet) a year from a well would have little impact on the hydrographic areas associated with the Caliente/Las Vegas route based on their perennial yields (Chapter 3, Section 3.2.2.2.3), even if multiple wells were placed in the same hydrographic area. As indicated in Table 6-104, about 50 percent of the route's length would be in areas with Designated Groundwater Basins, where the potential for groundwater depletion is watched carefully by the Nevada State Engineer's office. This does not mean that a contractor could not obtain water appropriations in these areas; the State Engineer would have the authority to approve such appropriations. The fact that requests for water appropriations under this action would be for minor amounts and for a short-term construction action should provide the State Engineer even more discretion. Other options would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 3,000 truckloads) to construction sites, or use a combination of these two actions. Obtaining a water appropriation from the State Engineer for a short-term construction use or using an approved allocation should ensure that groundwater resources would not be adversely affected.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck operations.

6.3.3.2.3.4 Caliente/Las Vegas Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all potential sites for an intermodal transfer station and routes. This section discusses construction- and operations-related impacts that would be unique to the Caliente intermodal station and Caliente/Las Vegas route.

Highway Construction and Upgrades. Section 6.3.3.2.1 discusses potential Caliente intermodal transfer station siting locations and impacts to biological resources and soils from construction of the station.

The predominant land cover types along the Caliente/Las Vegas route are creosote-bursage and Mojave mixed scrub (DIRS 104593-CRWMS M&O 1999, p. 3-32). The regional area for each vegetation type is extensive (DIRS 104593-CRWMS M&O 1999, pp. C1 to C5). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

Four threatened or endangered species occur along the route (DIRS 104593-CRWMS M&O 1999, p. 3-33). The desert tortoise occurs along the southern part of the route from near Alamo to Yucca Mountain (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). An approximately 100-kilometer (62-mile) section of U.S. 93 from Maynard Lake to the junction with I-15 is critical habitat for the desert tortoise (50 CFR 17.95). Slight alterations of habitat immediately adjacent to existing roads would affect desert tortoises because work would occur in the existing right-of-way. Tortoise populations are depleted for more than 1 kilometer (0.6 mile) on either side of roads with average daily traffic greater than 180 vehicles (DIRS 103160-Bury and Germano 1994, pp. 57 to 72). Two endangered species—the Pahranagat roundtail chub and the White River springfish—occur in Ash Springs or its outflow. The route crosses the outflow of Ash Springs, which is designated critical habitat for the White River springfish (50 CFR 17.95). Because improvements would occur on the existing roadway and the Nevada Department of Transportation would use standard practices to reduce erosion and runoff, road improvements would not adversely affect the species living there. Improvements to the existing highway would not affect southwestern willow flycatchers or their habitat in Pahranagat Valley (DIRS 152511-Brocoum 2000, pp. A-9 to A-13). Nine other special status species occur within 100 meters (330 feet) of this route (DIRS 104593-CRWMS M&O 1999, p. 3-33). Four of these species occur at Ash Springs or its outflow, and would not be affected for the reasons stated above for this site. The other five species would not be affected because construction activities would be restricted to the existing right-of-way, so occupied habitat would not be destroyed.

This route would cross eight areas designated as game habitat (DIRS 104593-CRWMS M&O 1999, p. 3-33). Habitat in these areas would be reduced slightly due to construction activities along existing roads. Game animals could be disrupted if they were in these areas during construction and would probably move away until the higher level of activity ceased.

Seven springs, riparian areas, or other wet areas occur near this route (DIRS 104593-CRWMS M&O 1999, p. 3-33). These areas may be jurisdictional wetlands or other waters of the United States. However, no formal delineation has occurred. Construction could increase sedimentation in these areas. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to mitigate impacts to these areas and would obtain individual or regional permits, as appropriate.

Impacts (such as increased water erosion and removal of land cover resulting in wind erosion) to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would be minimal but would include periodic disturbances of wildlife by noise from the additional truck traffic along this route. Trucks probably would kill individuals of some species, but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations.

6.3.3.2.3.5 Caliente/Las Vegas Route Cultural Resources

Section 6.3.3.1 discusses impacts to cultural resources that would be common to all the heavy-haul truck implementing alternatives.

Highway Construction and Upgrades. Highway upgrades and construction of the Caliente/Las Vegas heavy-haul truck route would be the same from the Caliente intermodal transfer station to the junction of U.S. 93 and State Route 375, just south of Hiko, as for the Caliente route (see discussion in Section 6.3.3.2.1). Following U.S. 93 south to the Apex area, the route passes through several sites and areas that have been tentatively identified as being important to American Indians (DIRS 155826-Nickens and Hartwell 2001, Table 8). The following places have been identified in the Pahranagat National Wildlife Refuge: the Black Canyon area, the Storied Rocks site farther south, and the Maynard Lake vicinity. The Black Canyon sites are listed on the *National Register of Historic Places.*

Archaeological surveys of the highway rights-of-way along this route have identified 128 archaeological sites, seven of which have been recommended as potentially significant (DIRS 155826-Nickens and Hartwell 2001, Appendix A). Three of the potentially significant archaeological sites are located in areas identified for highway upgrades. Another 86 remain unevaluated. Two of the unevaluated sites are historic graves.

Native Americans have identified the entire Pahranagat Valley, once home to the Pahranagat Paiutes, as an important cultural landscape (DIRS 155826-Nickens and Hartwell 2001, all). Earlier studies with Native Americans identified the Coyote Springs area and the Arrow Canyon Range valley south of Pahranagat as places of cultural importance.

Operations. Operation of the Caliente intermodal transfer station and the highways along Caliente/Las Vegas heavy-haul truck route would transport spent nuclear fuel and high-level radioactive waste through several areas identified as culturally important to Native Americans. In addition, the route passes through approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation, and the U.S. 93 segment passes near the Moapa Reservation.

6.3.3.2.3.6 Caliente/Las Vegas Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Caliente/Las Vegas route. Impacts from the associated intermodal transfer station in Caliente would be the same as those discussed in Section 6.3.3.2.1.

Highway Construction and Upgrades. Industrial safety impacts on workers from upgrading highways for the Caliente/Las Vegas route would be small (Table 6-105). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic-related fatalities from commuting workers and the

Table 6-105. Impacts to workers from industrial hazards from upgrading highways along the Caliente/Las Vegas route.

Group and industrial hazard category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	44	200
Lost workday cases	22	110
Fatalities	0.06	0.55
Noninvolved workers[d]		
Total recordable cases	2.6	11
Lost workday cases	1.0	4.3
Fatalities	0.003	0.01
Totals[e]		
Total recordable cases	47	210
Lost workday cases	23	110
Fatalities	0.06	0.56

a. Impacts are totals over about 46 months.
b. Includes impacts from periodic maintenance and resurfacing activities. Impacts are totals over 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

movement of construction materials and equipment. Table 6-106 lists the estimated fatalities from construction and commuter vehicle traffic.

Table 6-106. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Caliente/Las Vegas route for heavy-haul trucks.[a]

Activity	Kilometers[b]	Traffic fatalities	Vehicle emissions fatalities
Construction[c]			
Material delivery vehicles	41,000,000	0.7	0.09
Commuting workers	37,000,000	0.4	0.05
Subtotals	*78,000,000*	*1.1*	*0.13*
Operations[d]			
Commuting workers	200,000,000	2.0	0.26
Totals	***280,000,000***	***3.0***	***0.39***

a. Includes impacts from construction and operations of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impacts are totals over about 46 months.
d. Impacts are totals over about 24 years.

Operations. Incident-free radiological impacts listed in Table 6-107 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the Caliente/Las Vegas route. These impacts would include those from transportation along the route and along railways in Nevada leading to the Caliente intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-107. Health impacts from incident-free Nevada transportation for the Caliente/Las Vegas route heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments	Totals[b]
Involved workers			
Collective dose (person-rem)	38	1,400	1,400
Estimated latent cancer fatality	0.02	0.56	0.58
Public			
Collective dose (person-rem)	7	220	230
Estimated latent cancer fatality	0.003	0.11	0.11
Estimated vehicle emission-related fatalities	0.002	0.062	0.064

a. Impacts are totals for 24 years.
b. Totals might differ from sums of values due to rounding.

6.3.3.2.3.7 Caliente/Las Vegas Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along the Caliente/Las Vegas route and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes impacts from the operation of an intermodal transfer station at Caliente and periodic resurfacing of the highways and the planned Las Vegas Beltway.

The analysis of socioeconomic impacts assumed that Clark County would secure a loan to advance the construction schedule of the portion of the Las Vegas Beltway that would be part of the Caliente/Las Vegas route. The analysis based the estimates of impacts on two sources of information from Clark County on the cost of building a section of the Beltway. These sources estimate that modifications to the Northern Beltway would cost between $43.6 million (DIRS 103710-Clark County 1997, p. 2-7) and $463 million (DIRS 155112-Berger 2000, p. 29) (about $43.6 to $463 million in 2001 dollars). DOE believes the actual impact will be between the two values. The loan to Clark County for $43.6 million or $463 million, at a real rate of 3 percent, with repayment of the loan starting in 2010 and lasting for 30 years, is a part of the modeling to determine impacts to employment, population, real disposable income, and expenditures by State and local governments. (A *real* percentage rate is the premium paid in addition to the rate of inflation; a real rate plus the rate of inflation equals the nominal or quoted rate.) Clark County would repay the loan from tax revenues.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading public highways for the Caliente/Las Vegas route, advancing the scheduled completion of a portion of the Las Vegas Beltway, and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Employment for highway upgrades, excluding the Beltway, and construction of an intermodal transfer station would be about 832,000 worker-hours or 416 worker-years. The highway upgrades, excluding the Beltway, would cost $96.8 million, would take approximately 46 months, and would occur during the 48-month construction period anticipated for the Beltway. The analysis assumed that if DOE selected this route, Clark County would advance the construction schedule of the Beltway and would reconfigure the design to accommodate use by heavy-haul trucks. Constructing an intermodal transfer station would cost $25 million and require 18 months to complete. (Dollar values reported in this section are 2001 dollars unless otherwise stated.)

This section expresses values for socioeconomic measures (employment, population, real disposable income, Gross Regional Product, and State and local government expenditures) and for the potential impacts of change in those measures as a range of values. The first value refers to the outcome if the Beltway cost is $43.6 million; the second refers to the outcome if the cost is $463 million. DOE anticipates that the actual change would fall between the two values.

Employment

In the region of influence, increased employment of construction workers involved with upgrading the highways (including the Beltway) and with building an intermodal transfer station (direct workers) and other workers employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008 at between 588 and 1,979 persons. The increase in employment in Clark County would be between 544 and 1,910 workers, Nye County would gain between 8 and 29 workers, and Lincoln County would gain between 36 and 40 workers. The increases in Clark and Nye Counties would be less than 1 percent of the employment baseline for each county. The increase in Lincoln County would be less than 2 percent of the County’s employment baseline.

Population

Projected population increases in the region of influence that would result from construction work related to the Caliente/Las Vegas route would peak in 2009. During that year, population would be more than the baseline by between 500 and 2,002 individuals. The change in population for Clark County would be between 477 and 1,943 people, for Lincoln County between 13 and 17 people, and for Nye County between 10 and 42 people. The impacts from an increase in population as a result of increased employment opportunities would be less than 1 percent of each county’s population baseline. Because the increases in population in each county would be so small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station and the upgrading of highways and the Las Vegas Beltway. The increase above the baseline in real disposable income of people in the region of influence would peak in 2008 at between $19.0 million and $65.3 million. The region-wide increase in Gross Regional Product would peak in 2008 at between $33.1 million and $104.1 million. Increased State and local government expenditures resulting from highway upgrades and the intermodal transfer station construction project would peak in 2009 at between $1.7 million and $6.6 million. The Gross Regional Product, real disposal personal income, and expenditures by State and local governments would rise by less than 1 percent in Clark, Nye, and Lincoln Counties. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Caliente/Las Vegas heavy-haul truck route workers and indirect (support) workers would decrease by 516 to 2,123 when construction of the intermodal transfer station and highway upgrades (including the Beltway portion) ended in 2009. Clark County would lose between 506 and 2,087 of these jobs, Nye County would lose between 5 and 27 of these jobs, and Lincoln County would lose between 4 and 9 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Caliente/Las Vegas route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. If DOE selected this route, operations at an intermodal transfer station near the City of Caliente and use of heavy-haul trucks would begin in 2010 and continue until 2033. A workforce of 26 would be required for the intermodal transfer station. Direct employment for heavy-haul truck operations, including escorts, would be 120 workers.

To analyze impacts of operations for a Caliente/Las Vegas heavy-haul truck route, DOE considered three activities: operation of the intermodal transfer station, operation of heavy-haul trucks, and maintenance of highways and the Las Vegas Beltway.

Employment and Population

Employment associated with an intermodal transfer station and heavy-haul trucks would remain relatively level throughout operations. Total employment in the region of influence attributable to operation of a Caliente/Las Vegas route would average about 209 workers. The analysis determined that about 110 workers would come from Clark County, about 11 from Nye County, and 88 from Lincoln County. The impact on population would be about 359 additional residents in the region. About 224 persons would live in Clark County, about 25 in Nye County, and about 110 in Lincoln County. Additional employment and population for Lincoln County, which would experience the largest changes as a percentage of the baselines, would be about 3.3 percent of the employment baseline and 2.3 percent of the population baseline. These impacts would be within the range of historic changes in the county.

During the operational period of heavy-haul truck shipments, periodic road resurfacing would be needed. Employment (direct and indirect) in the region would increase by about 191 workers during the 2-year duration of resurfacing projects. DOE assumed that all the workers would come from Clark County-based employers. Overall, employment increases from periodic (every 8 years starting in 2016) highway resurfacing projects would be less than 1 percent of the baseline for Clark County. Given the short duration of each resurfacing project, there would be no perceptible change in the region’s population. Employees hired to resurface the highways and their families are included in the averages discussed below.

The net changes to employment and population from three operational activities associated with a Caliente/Las Vegas route during the 24 years of operations can be summarized. If the cost of the beltway was approximately $43.6 million, there would be an incremental increase of 225 jobs in the region of influence, 119 in Clark County, 13 in Nye County, and 93 in Lincoln County. This impact would be less than 1 percent of the baselines in Clark and Nye Counties, and 3.5 percent of the baseline in Lincoln County. If the cost of the beltway reaches $463 million, employment in the region of influence, while continuing to grow to approximately 1,137,000 positions, would have 108 fewer employment opportunities. Clark County would have 211 fewer positions, but Nye County would gain 10 positions and Lincoln County would gain 93 positions during the operations phase. Impacts to the baselines in Clark and Nye Counties would be less than 1 percent, but the change in Lincoln County would be 3.4 percent of the baseline.

The region of influence would experience a growth in population of an additional 440 residents, 292 in Clark County, 29 in Nye County, and 119 in Lincoln County. This impact would be less than 1 percent of the baselines in Clark and Nye Counties, but 2.5 percent of the baseline in Lincoln County. Because the impacts would be small in Clark and Nye Counties, impacts to housing or schools would be unlikely. The increase in population in Lincoln County would include an annual average of 32 school-age children. There would be no impact in the housing market in Lincoln County given the chronically high vacancy rate in housing (see Chapter 3, Section 3.1.7.4).

Economic Measures

Changes in employment and population would drive changes in economic measures attributable to the project. If the final loan amount was $43.6 million, real disposable income in the region of influence would rise throughout operations, starting at $3.9 million in 2010 and increasing to $14.7 million in 2033. The average would be $8.6 million. Gross Regional Product would also rise during operations; the average annual increase would be $13.4 million. State and local government expenditures would also increase with an average annual increase of $2.3 million. Increases to real disposable income, Gross Regional Product, and government expenditures would be less than 1 percent of the baselines for Clark and Nye Counties. The changes in Lincoln County would be more visible. Changes in real disposable income ($3.0 million annually) and government expenditures for the County would be approximately 2.5 and 3.0 percent of the baselines, respectively. The projected change in Gross Regional Product ($5.6 million annually) for the County would be 3.9 percent of the baseline. These changes would be within the range of historic short-term changes for Lincoln County.

If the final loan amount was $463 million, growth in real disposable income in the region of influence would slow throughout the operations period as the loan is repaid. Starting at $5.3 million above the baseline in 2010 and declining to $26.8 million below the baseline in 2033, growth in real disposable income would decline by an average of $24.2 million, or 0.043 percent of the region of influence's baseline during the operations phase. Real disposable income in Lincoln County would increase by an average of $3.0 million. This change would represent 2.5 percent of the County's baseline. Increases in Gross Regional product would average $468,000 in Nye County and $5.5 million in Lincoln County. The increase in Nye County would be less than 1 percent, but the change represents 3.8 percent of the baseline in Lincoln County. The rate of growth in Gross Regional Product would decline by an average of $12.1 million in Clark County and $6.1 million in the region of influence. These impacts would be less than 1 percent of the applicable baselines. Expenditures by State and local governments attributable to the project would average $100,000 in Nye County and $1.2 million in Lincoln County. The increase in Nye County would be less than 1 percent of the baselines, but the increase in Lincoln County would be 3.0 percent of the baseline. Growth in expenditures by State and local governments would slow by an average of $1.3 million in Clark County, an impact of less than 1 percent of the County's baseline. As population growth slows, there would also be a slowing in the rate of tax revenue collected and a slowing in the rate of population growth that would require a given level of public services.

In addition, DOE analyzed a sensitivity case in which all Lincoln County socioeconomic impacts were assumed to occur only in the City of Caliente. Under this assumption, city population would rise by 3 percent during construction and by about 8.7 percent during operations. Employment would rise by about 11 percent during construction and about 12 percent during operations.

6.3.3.2.3.8 Caliente/Las Vegas Route Noise and Vibration

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on the noise impacts that would be unique to the Caliente/Las Vegas heavy-haul truck implementing alternative.

Noise impacts of the Caliente intermodal transfer station would be the same as those discussed in Section 6.3.3.2.1.

Highway Construction and Upgrades. Construction activities for upgrading highways along the Caliente/Las Vegas route would occur on all sections with the exception of the section of I-15 between its intersection with U.S. 93 and the planned North Las Vegas Beltway. North Las Vegas, the Towns of Caliente and Indian Springs, and the small rural communities of Crystal Springs, Ash Springs, and Alamo would fall within the 2,000-meter (6,600-foot) region of influence for construction noise. The potential number of inhabitants would be highest near the greater Las Vegas area. There are scattered residences along U.S. 93 in the Pahranagat Valley.

Because the shipments would pass through a large population area, there would be a potential for noise impacts along the route.

Operations. The Caliente/Las Vegas route would by pass mostly rural communities, and would be confined to established highway systems. Three public schools in Alamo are in the region of influence along U.S. 93 and the Indian Springs school is in the region of influence along U.S. 95. However, the incremental noise increase due to the infrequent heavy-haul truck shipments would not alter the existing noise environment. Because the proposed intermodal transfer station would be on the western edge of Caliente and traffic would not travel through the city, traffic noise impacts in Caliente would be inconsequential. Estimated noise levels (1-hour average sound levels) in Crystal Springs, Ash Springs, Alamo, Indian Springs and Cactus Springs would increase by 0.3 to 2.0 dBA due to heavy-haul truck traffic. A potential *receptor* is the public school in Indian Springs, which also serves students from Cactus Springs. The Indian Springs school is about 300 meters (980 feet) south of U.S. 95. The incremental contribution of heavy-haul trucks at this distance from the highway would not be perceptible. Background traffic noise levels would be greatest along I-15 and the North Las Vegas Beltway, reducing the potential for heavy-haul truck noise to produce adverse effects to public receptors during daylight hours. No historic buildings would be affected by ground vibration. No sensitive ruins of cultural significance have been identified along this route.

On the Caliente/Las Vegas heavy-haul truck route, U.S. 93 passes within 5 kilometers (3 miles) of the Moapa Reservation. However, the distance from the highway to the reservation makes noise impacts unlikely. The estimated mean 1-hour increase in traffic noise due to heavy-haul trucks in this area would be 0.1 dBA over existing background traffic noise (DIRS 155825-Poston 2001, all). This increase would not be perceptible on the reservation. The heavy-haul truck route on U.S. 95 passes through about 1.6 kilometer (1 mile) of the Las Vegas Paiute Reservation. Because of the relatively large traffic volume on U.S. 95, the increase in traffic noise due to heavy-haul trucks in this area would not be perceptible (DIRS 155825-Poston 2001, all).

6.3.3.2.3.9 Caliente/Las Vegas Route Aesthetics

The Caliente intermodal transfer station would be near the entrance to Kershaw-Ryan State Park. Park visitors would receive short-term visual impacts from construction activities. In addition, park visitors could be affected by noise from construction activities that could lessen their recreational experience. These short-term impacts would exist only during construction.

During operation of the intermodal transfer station, noise and lighting probably would be discernible from Kershaw-Ryan State Park, especially during night operations, and would probably detract from the recreational experience. The use of shielded and directional lighting would limit the amount of viewable light from outside the facility operational area.

6.3.3.2.3.10 Caliente/Las Vegas Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Caliente/Las Vegas heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Caliente intermodal transfer station would produce the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-108 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Caliente/Las Vegas route. These quantities would be unlikely to be large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-108. Utilities, energy, and materials required for upgrades along the Caliente/Las Vegas route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Caliente-Las Vegas	377	5.5	110	0.55	0.80	21

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.4 *Sloan/Jean Route Implementing Alternative*

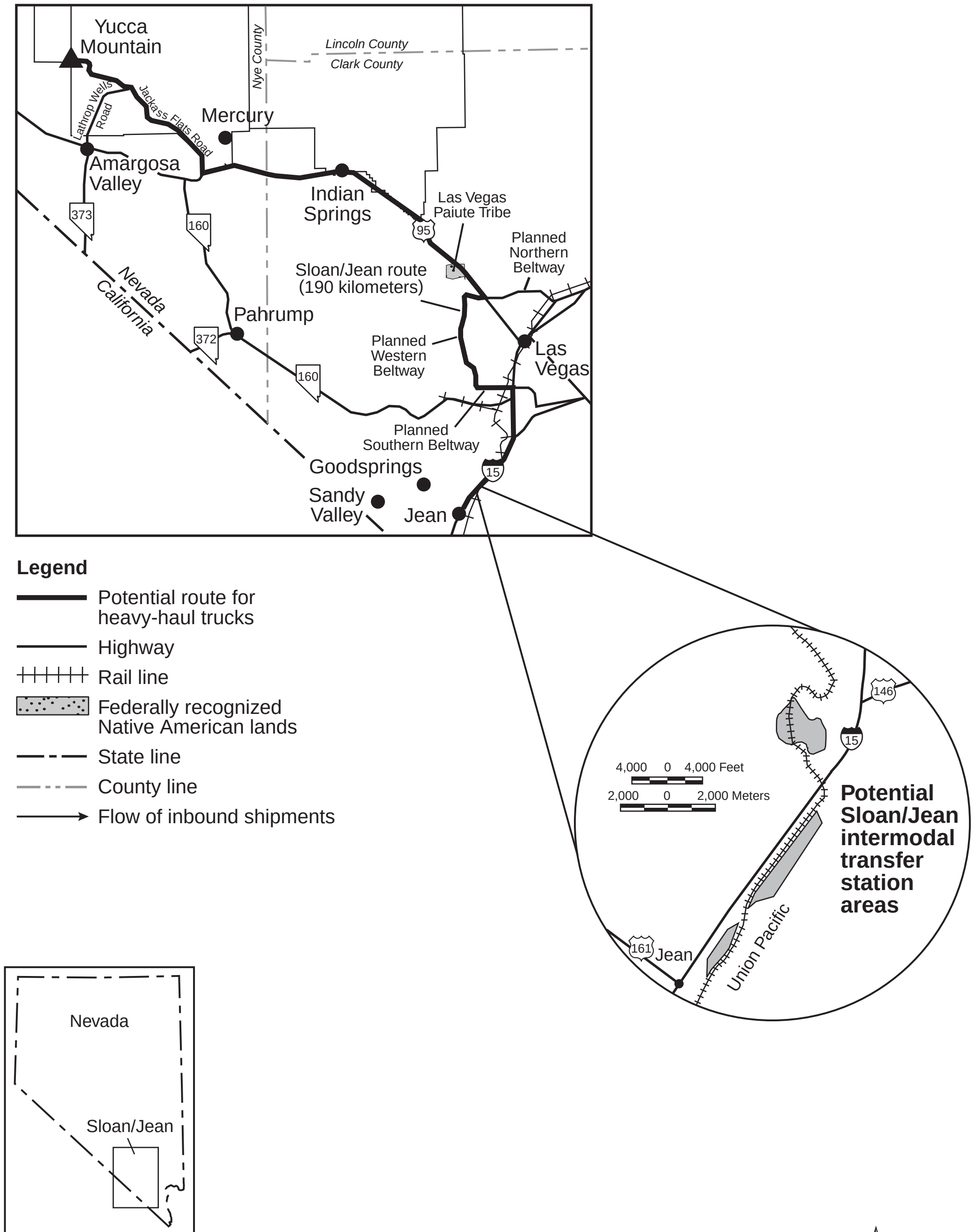
The Sloan/Jean route (Figure 6-25) is about 188 kilometers (117 miles) long. Heavy-haul trucks and escorts leaving a Sloan/Jean intermodal transfer station would enter I-15 at the Sloan interchange. The trucks would travel on I-15 to the exit to the southern portion of the proposed Las Vegas Beltway, and then travel northwest on the beltway. They would leave the beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. The travel time (vehicle in motion plus periodic short stops for inspections) associated with a Sloan/Jean route would be as much as 4 hours.

The three potential areas for an intermodal transfer station southwest of Las Vegas are between the existing Union Pacific sidings at Sloan and Jean. One area is on the east side of I-15, south of the Union Pacific rail underpass at I-15, and has an area of 3.3 square kilometers (811 acres). The second, which has an area of 3.1 square kilometers (758 acres), is south of the Sloan rail siding along the east side of the rail line. A third area is south of the second, directly north of the Jean interchange on I-15, and has an area of 1.0 square kilometer (257 acres). The estimated life-cycle cost of constructing and operating an intermodal transfer station and of operating heavy-haul trucks along the Sloan/Jean route would be about $444 million in 2001 dollars.

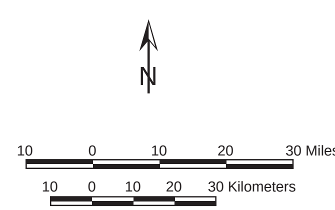
The following sections address impacts that would occur to land use; air quality; biological resources and soils; hydrology including surface water and groundwater; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts that would occur to aesthetics and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.4.1 Sloan/Jean Route Land Use and Ownership

This section describes anticipated land-use impacts that could occur from the construction and operation of the Sloan/Jean intermodal transfer station, upgrades of highways, and heavy-haul truck operations over



Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.



To convert kilometers to miles, multiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-25. Sloan/Jean heavy-haul truck route.

the Sloan/Jean route. Chapter 3, Section 3.2.2.2.1, describes the Sloan/Jean intermodal transfer station site and the associated truck route.

Highway Construction and Upgrades. At the Sloan/Jean intermodal station area there could be potential impacts related to the current use of the land. All three Sloan/Jean candidate sites are on land administered by the Bureau of Land Management. The northernmost area is in the Spring Mountain grazing allotment and the Ivanpah Valley desert tortoise area of critical environmental concern. The Bureau of Land Management has designated land east of the railroad as a gravel pit (community pit), but that land has not been worked; the area is open to fluid mineral leasing but closed to mining claims. The two southern areas are in the Jean Lake grazing allotment, a special recreation management area, and an area designated as available for sale or transfer. Both southern areas are open to fluid mineral leasing and mining claims (DIRS 104993-CRWMS M&O 1999, p. 21).

This route would require the disturbance of approximately 0.63 square kilometer (160 acres) of land from road upgrades and additional construction activities. Table 6-109 summarizes these disturbances.

The land under consideration would require a change in ownership from the Bureau of Land Management to DOE. The amount of land transferred from grazing lands to DOE would result in a small loss to the allotment. Because of the relatively small size of the required parcels and their proximity to roads and railways, the removal of these lands would be unlikely to affect livestock management. A potential loss of desert tortoise habit is discussed below. The amount of land that would be removed from fluid mineral leases is small and would be unlikely to cause long-term impacts. If the areas under consideration were already under lease, DOE would negotiate a transfer with the lessee.

Table 6-109. Land disturbances along the Sloan-Jean heavy-haul truck route.

Disturbance	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	0.47
Aggregate plants	0.08
Road widening	<0.01
Passing lanes	None
Truck turnouts	None
Fortymile Wash new road	0.04
Overnight stops	None
Mercury turnoff road	0.03
Total disturbed area	0.63

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

The removal of land from a special recreational management area would be unlikely to cause long-term impacts to recreational activities. The Bureau of Land Management could make other lands available for the recreational activities. This would require agreement between the Bureau and DOE before the start of construction activities.

The potential loss of lands from the Bureau of Land Management land sale/transfer program could cause a loss of potential tax revenue.

The Sloan/Jean route would require considerable improvements at the interchange with I-15. A small amount of land would be converted for the improvements. Section 6.3.3.1 discusses other impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Sloan/Jean intermodal transfer station or the Sloan/Jean route other than those described in Section 6.3.3.1.

6.3.3.2.4.2 Sloan/Jean Route Air Quality

This section describes anticipated nonradiological air quality impacts from construction activities and operations of an intermodal transfer station, highway construction and upgrades, and operation of heavy-haul trucks along the Sloan/Jean route. Such impacts would result from releases of criteria pollutants, including nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}) (see Section 6.3.3.1).

Carbon monoxide and PM_{10} are of particular interest along the Sloan/Jean route because some construction activities as well as heavy-haul truck transport would occur through the Las Vegas Basin, which is classified as a serious nonattainment area for those pollutants, and because the intermodal transfer station locations would be in or near the nonattainment area. PM_{10} and carbon monoxide emissions from intermodal transfer station construction are presented in Section 6.3.3.1. Intermodal transfer station construction emissions would be 15 percent of the PM_{10} General Conformity threshold and would be 2.3 percent of the carbon monoxide General Conformity threshold level.

Highway Construction and Upgrades. Section 6.3.3.1 discusses the methods used to estimate the air quality impacts for the construction activities for the Sloan/Jean route. PM_{10} emissions would be an estimated 41 metric tons (45 tons) per year, including estimated emissions for the accelerated construction activities of the southern and western portions of the Las Vegas Beltway. These emissions would be 64 percent of the General Conformity threshold level. Carbon monoxide emissions for highway construction and upgrades would be an estimated 33 metric tons (36 tons) per year. These emissions are 36 percent of the carbon monoxide General Conformity threshold level.

Operations. Section 6.3.3.1 discusses the air quality impacts associated with the operation of a locomotive at the Sloan/Jean intermodal transfer station. In addition to these operations, the operation of heavy-haul trucks along the Sloan/Jean route would affect the Las Vegas Valley air basin. Air quality impacts from heavy-haul trucks to this air basin would be small [0.62 metric tons (0.68 ton) per year of carbon monoxide] with emissions at less than 1 percent of the General Conformity threshold level. These emissions would result from 11 round trip heavy-haul trucks traveling through the Las Vegas Valley each week.

6.3.3.2.4.3 Sloan/Jean Route Hydrology

DOE anticipates limited impacts to surface water and groundwater during upgrades to Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these impacts as well as those from the construction and operation of an intermodal transfer station and operation of trucks on the Sloan/Jean route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed in Section 6.3.3.1 apply to surface water along the Sloan/Jean route.

The assessment in Appendix L compares what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer station sites (see Sections L.3.2.8 and L.4.2.2). The southernmost of the three locations for the Sloan/Jean station appears to be, at least in part, in a 100-year flood zone of a normally dry drainage channel (see Section L.3.2.8).

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Upgrades to the Sloan/Jean route would not require any water wells. The road upgrades would require an estimated total of about 9,200 cubic meters (8 acre-feet) of water (DIRS 104917-LeFever 1998, all). Options for obtaining this water would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 500 truckloads) to construction sites, or use a combination of these two actions.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul truck routes.

6.3.3.2.4.4 Sloan/Jean Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Sloan/Jean intermodal station and route.

Highway Construction and Upgrades. Potential Sloan/Jean intermodal transfer station site locations are between the existing Union Pacific rail sidings at Sloan and Jean. The dominant land cover type in these areas is creosote-bursage (DIRS 104593-CRWMS M&O 1999, p. 3-36). The land cover type at the site is extensive in the region (DIRS 104593-CRWMS M&O, pp. C1 to C5).

The three sites that DOE is considering for a Sloan/Jean intermodal transfer station are in the range of the desert tortoise, but none of the areas are critical habitat for the tortoise (50 CFR 17.95). The construction site would disturb approximately 0.2 square kilometer (50 acres) of tortoise habitat. The likelihood of tortoise death or injury due to construction activities would be small if DOE moved tortoises in the immediate area to a safe habitat. The pinto beardtongue (classed as sensitive by the Bureau of Land Management) occurs in two of the proposed locations of the Sloan/Jean intermodal transfer station (DIRS 104593-CRWMS M&O 1999, p. 3-36). If one of these sites was selected, DOE would conduct pre-activity surveys for this plant species and would avoid disturbance of occupied areas if possible. The construction of an intermodal transfer station at a site southwest of Sloan could cause bighorn sheep to avoid the eastern edge of their winter range in that area. There are no springs or other areas that could be classified as wetlands at the location of the intermodal transfer station (DIRS 104593-CRWMS M&O 1999, p. 3-36).

Predominant land cover types in nonurban areas along the route are creosote-bursage and Mojave mixed scrub (DIRS 104593-CRWMS M&O 1999, p. 3-36). The regional area for each vegetation type is extensive. Because areas disturbed by upgrade activities would be in or adjacent to existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

The only threatened or endangered species that occurs along the route is the desert tortoise. Desert tortoise habitat occurs throughout the length of the route (DIRS 103160-Bury and Germano 1994, pp. 57 to 72; 50 CFR 17.95). Construction activities could kill or injure desert tortoises; however, losses would be few because construction would occur only on the right-of-way and desert tortoises are uncommon along heavily traveled roads (DIRS 103160-Bury and Germano 1994, Appendix D, p. D12). Four other special status species occur along this route (DIRS 104593-CRWMS M&O 1999, p. 3-36), but construction activities would be limited to the road and adjacent areas; occupied habitat would not be destroyed and these species should not be affected.

This route would not cross any areas designated as game habitat and there are no springs or wetlands near the route. The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual or regional permits, as appropriate (DIRS 104593-CRWMS M&O 1999, p. 3-36). Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impacts to soils would be small.

6.3.3.2.4.5 Sloan/Jean Route Cultural Resources

Highway Construction and Upgrades. A total of 59 archaeological and historic sites have been recorded along existing highway rights-of-way along the Sloan/Jean heavy-haul truck route (DIRS 155826-Nickens and Hartwell 2001, Appendix A). None of these occur in areas along roads that would require upgrades.

There are seven archaeological sites near the location of the Sloan/Jean intermodal transfer station, none of which has been evaluated for potential eligibility for the *National Register of Historic Places* (DIRS 155826-Nickens and Hartwell 2001, Appendix A). Possible unrecorded sites in the intermodal transfer station location include some associated with the original construction of the railroad in the early part of the 20th century, such as construction camps. The location of the "Last Spike," where the last two segments of the railroad were joined occurs in the vicinity of the site.

No areas or sites of cultural importance to Native Americans have been identified along the Sloan/Jean route or at the intermodal transfer station location, although field studies have not been completed. The route follows a portion of U.S. 95 that passes though approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation.

Operations. Based on currently available information, operation of a Sloan/Jean intermodal transfer station and heavy-haul truck route would have no impacts on cultural resources.

6.3.3.2.4.6 Sloan/Jean Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Sloan/Jean route. Impacts from the associated intermodal transfer station in the Sloan/Jean area would be the same as those discussed in Section 6.3.3.1.

Highway Construction and Upgrades. Industrial safety impacts on workers from upgrading highways for the Sloan/Jean route would be small (Table 6-110). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatality risks for workers, and traffic fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-111 lists the estimated fatalities from construction and commuter vehicle traffic.

Operations. The incident-free radiological impacts listed in Table 6-112 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the Sloan/Jean route. These impacts would include transportation along the Sloan/Jean route as well as transportation along railways in Nevada leading to the Sloan/Jean intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-110. Health impacts to workers from industrial hazards from upgrading highways along the Sloan/Jean route.

Group and industrial impact category	Construction[a]	Operations[b]
nvolved workers		
Total recordable cases[c]	23	120
Lost workday cases	11	66
Fatalities	0.032	0.33
Noninvolved workers[d]		
Total recordable cases	1.4	6.8
Lost workday cases	0.5	2.5
Fatalities	0.001	0.007
otals[e]		
Total recordable cases	24	130
Lost workday cases	12	68
Fatalities	0.033	0.34

a. Impacts are totals over about 48 months.
b. Includes impacts for periodic maintenance and resurfacing. Impacts are totals over about 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Table 6-111. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Sloan/Jean route for heavy-haul trucks.

Activity	Kilometers[a]	Traffic fatalities	Vehicle emissions fatalities
Construction[b]			
Material delivery vehicles	17,000,000	0.3	0.04
Commuting workers	21,000,000	0.2	0.03
Subtotals	*38,000,000*	*0.5*	*0.06*
Operations[c]			
Commuting workers	120,000,000	1.2	0.16
Totals	*170,000,000*	*1.7*	*0.23*

a. Includes impacts of construction and operation of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impacts are totals over about 48 months.
d. Impacts are totals over 24 years.

Table 6-112. Health impacts from incident-free Nevada transportation for the Sloan/Jean heavy-haul truck implementing alternative.[a]

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	38	1,200	1,200
Estimated latent cancer fatalities	0.02	0.48	0.50
Public			
Collective dose (person-rem)	7	330	340
Estimated latent cancer fatalities	0.003	0.17	0.17
Estimated vehicle emission-related fatalities	0.002	0.19	0.19

a. Impacts are totals for 24 years.
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums of values due to rounding.

6.3.3.2.4.7 Sloan/Jean Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along the Sloan/Jean route, constructing and modifying a section of the planned Las Vegas Beltway, and building an intermodal transfer station for heavy-haul truck transportation. The discussion includes the impacts of operating an intermodal transfer station near Sloan/Jean in Clark County and of periodic resurfacing of the highways and Beltway.

This analysis of socioeconomic impacts assumed that Clark County would secure a loan to advance the construction schedule of the portion of the Las Vegas Beltway that would be part of this heavy-haul truck route. DOE estimates that modifications to the Beltway would cost between $98.1 million and $790 million in 2001 dollars. DOE believes the actual impacts would be between the two values. A loan to Clark County for $98.1 or $790 million, at a real rate of 3 percent, with repayment of the loan starting in 2010 and lasting for 30 years, is a part of the modeling to determine the impacts to employment, population, real disposable income, and expenditures by State and local governments. (A *real* percentage rate is the premium paid in addition to the rate of inflation; a real rate plus the rate of inflation equals the nominal or quoted rate.) Clark County would repay the load from tax revenues. DOE assumes most repayment funds would be from sources the county has already identified for completion of the Beltway.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading existing highways for a Sloan/Jean route, advancing the construction schedule for modifying a portion of the planned Las Vegas Beltway, and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. Upgrading the existing highways for the route, excluding the Beltway, would cost about $20.8 million and would require 48 months to complete. The upgrades to the highways would occur during the 48-month construction period for the planned portion of the Beltway. Building an intermodal transfer station would cost $25 million and would require 18 months. If DOE selected this route, the Beltway construction schedule would be advanced to accommodate use by heavy-haul trucks. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Employment

The dynamics of specific construction projects include a period of brief, intense elevation in project-related employment, followed by an abrupt decrease in associated employment opportunities as construction workers move to other projects. Composite employment would peak in the region of influence in 2008, would be approximately 631 workers under the $98.1 million beltway assumption, and would peak in 2006 at 3,047 workers under the estimated $790 million assumption. Under the entire range of estimated costs, Clark County would provide more than 96 percent of the workers. Clark County would gain 620 to 2,996 workers, Nye County would gain 9 to 42 workers, and Lincoln County would gain 2 to 9 workers. The change in employment for Clark, Nye, and Lincoln Counties would be less than 1 percent of their employment bases.

Population

Population increases in the region of influence due to a Sloan/Jean route and intermodal transfer station construction would peak in 2009. During that year, the incremental increase in population for Clark County would be between 532 and 2,951 people, for Lincoln County between 1 and 8 people, and for Nye County between 11 and 63 people. The impacts due to an increase in population as a result of increased employment opportunities would be less than 1 percent of each county's population baseline. Because the increases in population in each county would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station, upgrading of highways, and construction of the Las Vegas Beltway. The increase in real disposable income of people in the three-county region of influence would peak in 2008 at between $20.7 million and $97.3 million. The region-wide increase in Gross Regional Product would peak in 2008 at between $36.0 million and $153.2 million. Increased State and local government expenditures would peak in 2009 at between $1.8 million and $9.9 million. The Gross Regional Product, real disposal personal income, and expenditures by State and local governments would rise by less than 1 percent of the baselines in Clark, Nye, and Lincoln Counties. (Dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Sloan/Jean heavy-haul route workers and indirect (support) workers would decrease by 588 to 3,240 when construction of the intermodal transfer station and highway upgrades (including the Beltway portion) ended in 2009. Clark County would lose between 579 and 3,185 of these jobs, Nye County would lose between 8 and 45 of these jobs, and Lincoln County would lose between 1 and 10 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Sloan/Jean route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station near Sloan/Jean and the use of heavy-haul trucks would begin in 2010 and last until 2033. A workforce of about 26 would be required for the intermodal transfer station. Direct employment for heavy-haul truck operations over a Sloan/Jean route, including shipment escorts, would be about 66 workers. The analysis assumed that operations workers would reside in Clark County.

To analyze the impacts of using a Sloan/Jean route for heavy-haul trucks, DOE considered three activities: the operation of the intermodal transfer station, the operation of heavy-haul trucks, and the maintenance of the highways and the Las Vegas Beltway.

Employment and Population

Employment associated with the operations of an intermodal transfer station and heavy-haul trucks would remain relatively level throughout operations. Total employment in the region of influence attributable to a Sloan/Jean route would average about 107 workers. The analysis determined that about 99 workers would come from Clark County and that the other 8 would come from outside the three-county region of influence. The impact on the population from operating heavy-haul trucks and the intermodal transfer station would be about 129 additional residents in the region. About 127 persons would live in Clark County, and 2 people would live in Nye County. Lincoln County would be unlikely to gain population as a result of this project. Impacts to the employment and population baselines in Nye and Clark Counties would be less than 1 percent. Because the incremental increase in population would be so small, impacts to housing and the school system would be unlikely.

Because of the periodic need to resurface highways used by heavy-haul trucks, construction maintenance employment would increase in the years during which these projects occurred. Resurfacing would occur from 2016 to 2017, 2024 to 2025, and 2032 to 2033. During these years, total employment in the region of influence would increase by about 42 jobs and decline as maintenance activities ended. DOE assumed that virtually all of the resurfacing construction employees would come from Clark County employers. Employment changes from periodic (every 8 years) highway-resurfacing projects would be less than 1 percent of the employment baseline in Clark County. The employees who would resurface the roads and their families are included in the employment and population averages discussed above for the operations phase.

Net changes to employment and population from all three portions of the Sloan/Jean heavy-haul truck route during the 24-year operations phase can be summarized. There would be an incremental average annual increase of 48 positions in the region of influence, 47 of them in Clark County if the cost of the beltway was approximately $98.1 million. The region of influence would experience a growth in population of 53 additional residents, 48 in Clark County and 5 in Nye County. These impacts would be less than 1 percent of the baselines. If the cost of the beltway reaches $790 million, the region of influence, while continuing to grow to an average of 1.1 million jobs, would have 501 fewer employment positions. Approximately 497 of these positions would have been in Clark County. Population, which is driven by employment opportunities, would be affected. The region of influence (with an average of 2.29 million residents) would have 1,016 fewer residents, all of whom would have lived in Clark County. Impacts to populations and employment at the upper range of the cost estimates would be less than 1 percent of the baselines.

Economic Measures

Changes in employment and population would drive changes in economic measures attributable to the project. If the final loan amount was $98.1 million, real disposable income in the region of influence would oscillate above and below the baseline throughout the operations period. The average would be $616,000 below the region of influence's $55.7 million average baseline. Gross Regional Product would rise during operations, with the average increase being $5.8 million. Annual State and local government expenditures would increase, with the average increase being $176,000. Increases to real disposable income, Gross Regional Product, and government expenditures would be less than 1 percent of the baselines for Clark, Nye, and Lincoln Counties.

If the final loan amount was $790 million, impacts would be more visible, but still less than 1 percent of the economic measure baselines for each county. Growth in real disposable income in the region of influence would slow throughout the operations period as the loan is repaid. Growth in real disposable income would decline by an average of $54.7 million, or 0.0981 percent of the region of influence's baseline during the operations phase. Decreases in Gross Regional Product would average $26.3 million in the three-county region of influence. The decline in the growth rate would be less than 1 percent of each county's baseline. A slowing in expenditures by State and local governments attributable to the project would average $3.7 million annually region-wide. As population growth slowed, there would be slowing in the rate of tax revenue collected and a slowing in the rate of population growth that would require a given level of public services.

6.3.3.2.4.8 Sloan/Jean Route Noise and Vibration

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on the noise impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Highway Construction and Upgrades. There are residences and commercial businesses near the three potential sites for an intermodal transfer station in the Sloan/Jean area. Construction noise would occur during daylight hours and would be a temporary source of elevated noise in the area. Nighttime noise impacts would be unlikely because construction activities would not occur at night.

For the Sloan/Jean route, southern and western Las Vegas, the Town of Indian Springs, and the small rural community of Jean would be within the 2,000-meter (6,600-foot) region of influence for construction noise. Construction activities would occur on all sections of the route with the exception of I-15 between its interchange at Sloan and the planned Southern Las Vegas Beltway. Because the number of inhabitants of the region of influence would be high because the route passes around the greater Las Vegas area and includes other small rural communities and towns, there is a potential for construction noise impacts.

Operations. The presence of residences and commercial businesses near the Sloan/Jean location would make an intermodal transfer station a potential source of more noise complaints than the more remote locations. However, because operational noise in the vicinity of Sloan/Jean would not be much higher than the levels associated with most other light industrial areas, noise impacts would be unlikely. Railcar switching would be the greatest source of noise.

The Sloan/Jean route would use established highway systems with wide shoulders. The incremental noise increase due to the infrequent heavy-haul truck shipments would not alter the existing noise environment. Estimated noise levels (1-hour average sound levels) at Indian Springs and Cactus Springs would increase by about 0.4 dBA [at 15 meters (50 feet) from the road] due to heavy-haul truck traffic. Background traffic noise levels would be greatest along the western Beltway, reducing the potential for heavy-haul truck noise to cause adverse effects to public receptors during daylight hours. A potential receptor is the public school in Indian Springs which also serves students from Cactus Springs. The Indian Springs school is about 300 meters (980 feet) south of U.S. 95. The incremental contribution of heavy-haul trucks at this distance from the highway would not be perceptible. No historic buildings would be affected by ground vibration. No sensitive ruins of cultural significance have been identified along this route.

The Sloan/Jean heavy-haul truck route on U.S. 95 passes through about 1.6 kilometer (1 mile) of the Las Vegas Paiute Reservation. Because of the relatively large traffic volume on U.S. 95, the increase in traffic noise due to heavy-haul trucks in this area would not be perceptible (DIRS 155825-Poston 2001, all).

6.3.3.2.4.9 Sloan/Jean Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy, and materials impacts that would be unique to the Sloan/Jean heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Sloan/Jean intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-113 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Sloan/Jean route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-113. Utilities, energy, and materials required for upgrades along the Sloan/Jean route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Sloan/Jean	188	1.7	27	0.24	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses utilities, energy, and materials needs for operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.5 *Apex/Dry Lake Route Implementing Alternative*

The Apex/Dry Lake route (Figure 6-26) is about 183 kilometers (114 miles) long. Heavy-haul trucks and escorts would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway and travel west on the Beltway. They would leave the Beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. The travel time (vehicle in motion plus periodic short stops for inspections) associated with an Apex/Dry Lake route would be as much as 4 hours.

The potential sites for the Apex/Dry Lake intermodal transfer station are in areas northeast of Las Vegas between the Union Pacific rail sidings at Dry Lake and at Apex. Three areas are available for station siting (see Figure 6-26). The first area is directly adjacent to the Dry Lake siding. This area is large [3.5 square kilometers (880 acres)] and has flat topography; it is adjacent to and west of the Union Pacific line. The second is a smaller area [0.18 square kilometer (45 acres)] on the same side of the Union Pacific mainline, a short distance northeast of the 3.5-square-kilometer area, and also has flat topography. This area would be used in combination with a portion of the first area. These two areas are bounded by hills to the north and by a wash and private land to the south. The third area, which is east of I-15, is adjacent to and west of the Union Pacific line and south of where the line crosses I-15. This location has an area of 0.96 square kilometer (240 acres). Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary. The estimated life-cycle cost to build and operate an intermodal transfer station and to operate heavy-haul trucks along the Apex/Dry Lake route would be about $387 million in 2001 dollars.

The following sections address impacts that would occur to land use; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts to hydrology from the construction and operation of an intermodal transfer station, upgrading of highways, and operation of heavy-haul trucks on an Apex/Dry Lake route would be the same as those discussed in Section 6.3.3.2.4 for a Sloan/Jean route.

Highway Construction and Upgrades. The construction of the Sloan/Jean intermodal transfer station would have the same utilities, energy and materials impacts as those discussed in Section 6.3.3.1.

Table 6-113 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Sloan/Jean route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-113. Utilities, energy, and materials required for upgrades along the Sloan/Jean route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Sloan/Jean	188	1.7	27	0.24	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses utilities, energy, and materials needs for operation of an intermodal transfer station.

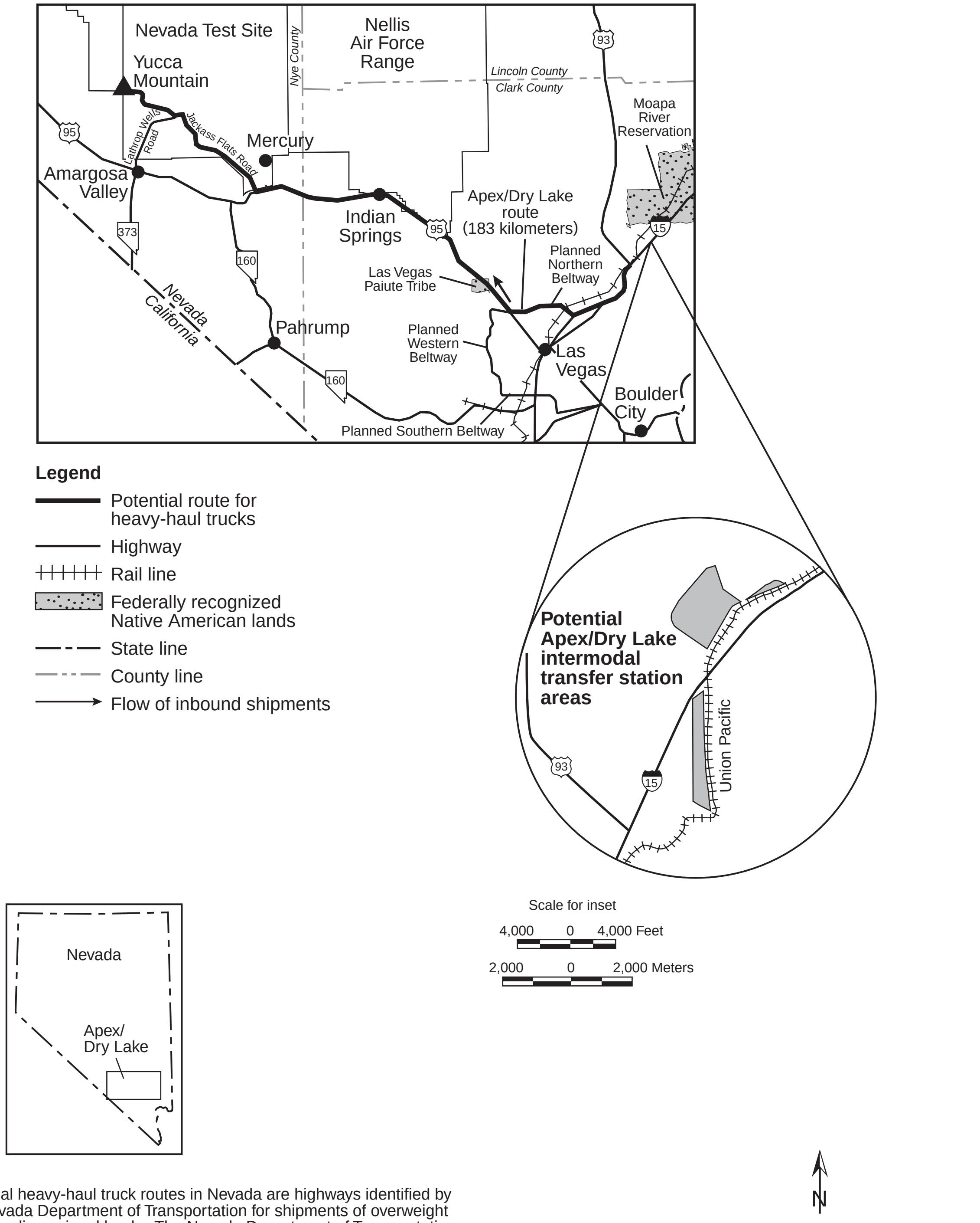
Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.3.2.5 *Apex/Dry Lake Route Implementing Alternative*

The Apex/Dry Lake route (Figure 6-26) is about 183 kilometers (114 miles) long. Heavy-haul trucks and escorts would leave the intermodal transfer station at the Apex/Dry Lake location and enter I-15 at the Apex interchange. The trucks would travel south on I-15 to the exit to the proposed northern Las Vegas Beltway and travel west on the Beltway. They would leave the Beltway at U.S. 95, and travel north on U.S. 95 to the Mercury entrance to the Nevada Test Site. The trucks would travel on Jackass Flats Road on the Nevada Test Site to the Yucca Mountain site. The travel time (vehicle in motion plus periodic short stops for inspections) associated with an Apex/Dry Lake route would be as much as 4 hours.

The potential sites for the Apex/Dry Lake intermodal transfer station are in areas northeast of Las Vegas between the Union Pacific rail sidings at Dry Lake and at Apex. Three areas are available for station siting (see Figure 6-26). The first area is directly adjacent to the Dry Lake siding. This area is large [3.5 square kilometers (880 acres)] and has flat topography; it is adjacent to and west of the Union Pacific line. The second is a smaller area [0.18 square kilometer (45 acres)] on the same side of the Union Pacific mainline, a short distance northeast of the 3.5-square-kilometer area, and also has flat topography. This area would be used in combination with a portion of the first area. These two areas are bounded by hills to the north and by a wash and private land to the south. The third area, which is east of I-15, is adjacent to and west of the Union Pacific line and south of where the line crosses I-15. This location has an area of 0.96 square kilometer (240 acres). Because this area is between the Dry Lake and Apex sidings, the construction of an additional rail siding would be necessary. The estimated life-cycle cost to build and operate an intermodal transfer station and to operate heavy-haul trucks along the Apex/Dry Lake route would be about $387 million in 2001 dollars.

The following sections address impacts that would occur to land use; air quality; hydrology; biological resources and soils; cultural resources; occupational and public health and safety; socioeconomics; noise and vibration; and utilities, energy, and materials. Impacts to hydrology from the construction and operation of an intermodal transfer station, upgrading of highways, and operation of heavy-haul trucks on an Apex/Dry Lake route would be the same as those discussed in Section 6.3.3.2.4 for a Sloan/Jean route.



10 0 10 20 30 Miles
10 0 10 20 30 Kilometers

Potential heavy-haul truck routes in Nevada are highways identified by the Nevada Department of Transportation for shipments of overweight and overdimensional loads. The Nevada Department of Transportation would issue permits that specified approved routing for heavy-haul truck shipments on Nevada highways. The State of Nevada could designate alternative and additional preferred routes as specified in 49 CFR 397.103, that could include routes other than ones through the Las Vegas metropolitan area.

To convert kilometers to miles, mulitiply by 0.62137.

Source: Modified from DIRS 104588-YMP (1998, all).

Figure 6-26. Apex/Dry Lake heavy-haul truck route.

Impacts to aesthetics and waste management would be the same as those discussed in Section 6.3.3.1 and are, therefore, not repeated here. Section 6.3.4 discusses the potential for transportation activities to cause environmental justice impacts in Nevada.

6.3.3.2.5.1 Apex/Dry Lake Route Land Use and Ownership

This section describes estimated land-use impacts that could occur from the construction and operation of the Apex/Dry Lake intermodal transfer station, upgrades of highways, and heavy-haul truck operations on the Apex/Dry Lake route. Chapter 3, Section 3.2.2.2.1, describes the Apex/Dry Lake intermodal transfer station site and associated truck route.

Highway Construction and Upgrades. The Apex/Dry Lake intermodal transfer station site could have potential impacts related to the current use of the land. The southern intermodal transfer station parcel east of I-15 at the Apex/Dry Lake site is on land administered by the Bureau of Land Management. Transfer of the property to DOE would be necessary. The northern areas have several infrastructure corridors (power line, telephone, and road rights-of-way). Right-of-way access through these areas would have to be leased by, purchased by, or transferred to DOE. The northern parcels are in the Dry Lake grazing allotment and a planned utility corridor. It is also open to mineral leasing and mining claims. One area has been designated as available for sale or transfer. This site also is in the area of the Apex Industrial Park that began development in mid-1999.

The parcel in the grazing allotment would lose a small parcel of land, if chosen. However, due to the proximity of the parcel to existing roads and rail lines, the transfer of this land to DOE would not divide the grazing allotment and would cause no livestock movement or watering problems.

The relatively small area of an intermodal transfer station location would not create long-term impacts to mineral exploration or mining claims unless the lands are already leased. If there were leases, DOE would negotiate with the lease holders for use of the property.

Because the transfer station parcels are in an area designated for sale or transfer by the Bureau of Land Management, the Bureau would have to remove the lands from this program to transfer them to DOE. The removal of these lands from the sale/transfer program could affect private, municipal or county, or other stakeholders. Tax revenue could be lost through the loss of economic development. This impact could be mitigated by the replacement of removed land with other parcels with similar characteristics. This route would require the disturbance of 0.63 square kilometer (155 acres) of land for road upgrades and additional construction activities. Table 6-114 summarizes these disturbances.

The Apex/Dry Lake route would require considerable improvements at the interchange at I-15. A small amount of land would be converted for the improvements. Section 6.3.3.1 discusses impacts on land use from upgrading Nevada highways for use by heavy-haul trucks.

Operations. There would be no direct land-use impacts associated with the operation of the Apex/Dry Lake intermodal transfer station or the Apex/Dry Lake route other than those described in Section 6.3.3.1.

Table 6-114. Land disturbances along the Apex/Dry Lake heavy-haul truck route.

Disturbances	Area disturbed[a] (square kilometers)[b]
Haul road disturbed area	0.47
Aggregate plants	0.08
Road widening	None
Passing lanes	None
Truck turnouts	None
Fortymile Wash new road	0.04
Overnight stops	None
Mercury turnoff road	0.03
Total disturbed area	0.63

a. Numbers approximate due to rounding.
b. To convert square kilometers to acres, multiply by 247.1.

6.3.3.2.5.2 Apex/Dry Lake Route Air Quality

This section describes anticipated nonradiological air quality impacts from the construction and operation of an intermodal transfer station, highway construction and upgrades, and operation of heavy-haul trucks along the Apex/Dry Lake route. Such impacts would result from releases of criteria pollutants, nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}) (see Section 6.3.3.1). Carbon monoxide and PM_{10} are of particular interest along the Apex/Dry Lake Route because heavy-haul truck transport would occur through the Las Vegas Basin, which is classified as a nonattainment area for these pollutants. PM_{10} and carbon monoxide emissions from intermodal transfer station construction are presented in Section 6.3.3.1. Intermodal transfer station construction emissions would be 15 percent of the PM_{10} General Conformity threshold level and would be 2.3 percent of the carbon monoxide General Conformity threshold level.

Highway Construction and Upgrades. Section 6.3.3.1 discusses the methods used to estimate air quality impacts from the construction activities for the Apex/Dry Lake route. PM_{10} emissions would be an estimated 45 metric tons (50 tons) per year, including estimated emissions for the accelerated construction activities of the northern portion of the Las Vegas Beltway. These emissions would be 71 percent of the General Conformity threshold level. Carbon monoxide emissions for highway construction and upgrades would be an estimated 35 metric tons (39 tons) per year. These emissions are 39 percent of the carbon monoxide General Conformity threshold level.

Operations. The air quality impacts for the operations of an intermodal transfer station locomotive at the Apex/Dry Lake intermodal transfer station would be identical to those described for the Sloan/Jean station (see Section 6.3.3.2.4). In addition, heavy-haul trucks would pass through the Las Vegas Valley air basin. The air quality impacts from the heavy-haul trucks to this air basin would be small [0.46 metric tons (0.51 ton] per year carbon monoxide) with emissions at less than 1 percent of the General Conformity threshold level. These emissions would result from 11 roundtrip heavy-haul trucks traveling through the Las Vegas Valley each week.

6.3.3.2.5.3 Apex/Dry Lake Route Hydrology

DOE anticipates limited impacts to surface water and groundwater during upgrades to Nevada highways so they could accommodate daily use by heavy-haul trucks. This section discusses these impacts as well as those from the construction and operation of an intermodal transfer station and operation of trucks on the Apex/Dry Lake route. Section 6.3.3.1 discusses the hydrology impacts that would be common to all of the heavy-haul truck implementing alternatives. This section focuses on the hydrology impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Surface Water

Section 6.3.3.1 discusses the impacts to surface water from the construction and operation of an intermodal transfer station and upgrades to highways. The common impacts discussed in that section apply to surface water along the Sloan/Jean route.

The assessment in Appendix L presents a comparison of what is known about the floodplains, springs, and riparian areas at the three candidate intermodal transfer sites (see Sections L.3.2.7 and L.4.2.2) The southern most of the three locations considered for the Apex/Dry Lake intermodal transfer site appears to be, at least in part, within a 100-year flood zone of a normally dry drainage channel (see Section L.3.2.7).

Groundwater

Highway Construction and Upgrades. Section 6.3.3.1 discusses the impacts to groundwater from the construction of an intermodal transfer station. Upgrades to the Apex/Dry Lake route would not require any water wells. The road upgrades would require an estimate total of about 9,200 cubic meters (8 acre-feet) of water (DIRS 104917-LeFever 1998, all). Options for obtaining this water would be to lease temporary water rights from individuals along the route, ship water from other permitted resources by truck (about 500 truckloads) to construction sites, or use a combination of these two actions.

Operations. Section 6.3.3.1 discusses impacts to groundwater from the operation of an intermodal transfer station, highway maintenance, and heavy-haul routes.

6.3.3.2.5.4 Apex/Dry Lake Route Biological Resources and Soils

Section 6.3.3.1 discusses impacts to biological resources from the construction and operation of an intermodal transfer station and upgrades to highways that would be common to all intermodal transfer stations and routes. This section discusses the construction- and operations-related impacts that would be unique to the Apex/Dry Lake intermodal station and route.

Highway Construction and Upgrades. DOE has identified three areas for the construction of an Apex/Dry Lake intermodal transfer station. The predominant land cover type at these sites (creosote-bursage) and it is extensively distributed in the region (DIRS 104593-CRWMS M&O 1999, pp. 3-36 and C1 to C5). Considerable industrial development has occurred near the potential sites. The three sites are in the range of the threatened desert tortoise, although none is in an area considered to be critical habitat for the tortoise (50 CFR 17.95). The construction site would disturb approximately 0.2 square kilometer (50 acres) of desert tortoise habitat. The likelihood of death or injury to tortoises due to construction activities would be small if DOE conducted surveys for tortoises in areas to be disturbed and moved tortoises in the immediate area out of harm's way. Geyer's milk vetch (BLM sensitive) occurs on the southern edge of one of the proposed locations of the Apex/Dry Lake intermodal transfer station (DIRS 104593-CRWMS M&O 1999, p. 3-37). If this location for an intermodal transfer station was selected, DOE would conduct pre-activity surveys for this plant's species and would avoid occupied habitat if possible. There are no designated game habitats at the proposed locations for the intermodal transfer station, or any springs or other areas that could be classified as wetlands (DIRS 104593-CRWMS M&O 1999, p. 3-37).

The predominant land cover types along the Apex/Dry Lake heavy-haul truck route are creosote-bursage and Mojave mixed scrub, which are common throughout this region (DIRS 104593-CRWMS M&O 1999, pp. 3-34, and C1 to C5). Because areas disturbed by upgrade activities would be in or adjacent to the existing rights-of-way and the areas have been previously degraded by human activities, impacts would be small.

The only resident threatened or endangered species that occurs along the Apex/Dry Lake route is the desert tortoise. Desert tortoise habitat occurs along the entire length of the route (DIRS 103160-Bury and Germano 1994, pp. 57 to 72; 50 CFR 17.95). Construction activities could kill or injure desert tortoises; however, losses would be few because construction would occur only on the right-of-way and desert tortoises are uncommon adjacent to heavily traveled roads (DIRS 103160-Bury and Germano 1994, Appendix D, p. D12). Three other special status species occur along this route (DIRS 104593-CRWMS M&O 1999, p. 3-35) but because construction activities would be limited to the road and adjacent areas, occupied habitat would not be destroyed and these species should not be affected.

This route would not cross any areas designated as game habitat or springs or possible wetlands (DIRS 104593-CRWMS M&O 1999, p. 3-35). The corridor crosses a number of ephemeral streams that may be classified as waters of the United States. DOE would work with the State of Nevada and the U.S. Army Corps of Engineers to minimize impacts to these areas, and obtain individual, regional, or nationwide permits, as appropriate. Impacts to soils would be transitory and small and would occur only along the shoulders of existing roads.

Operations. Impacts from operations would include periodic disturbances of wildlife from activities at the intermodal transfer station and additional truck traffic along this route. Trucks probably would kill individuals of some species but losses would be few and unlikely to affect regional populations of any species. No additional habitat loss would occur during operations. Impact to soils would be small.

6.3.3.2.5.5 Apex/Dry Lake Route Cultural Resources

Highway Construction and Upgrades. A total of 51 archaeological and historic sites have been recorded along the highway rights-of-way that comprise the Apex/Dry Lake intermodal transfer station site and heavy-haul truck route (DIRS 155826-Nickens and Hartwell 2001, all). None of these previously recorded cultural sites are in locations proposed for upgrades.

There are no recorded cultural resources that would be affected by the construction of an Apex/Dry Lake intermodal transfer station. However, an original segment of the historic Arrowhead Trail Highway passes through the northern intermodal transfer station site location, and includes the archaeological remains of a motel and gas station. Based on previous archaeological studies in the larger area, there is a probability that there are one or more construction camps from the initial railroad construction era in the proposed intermodal transfer station locations as well.

The route follows a portion of U.S. 95 that passes though approximately 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation. The intermodal transfer station would be along I-15, about 3 kilometers (2 miles) south of the Moapa Paiute Reservation. Construction of the intermodal transfer station and use of U.S. 95 for this route would not have adverse impacts on Native American sites or values.

Operations. Use of an Apex/Dry Lake intermodal transfer station and heavy-haul truck route would not involve impacts (such as disturbing the sites or crushing artifacts) to known cultural resource sites.

6.3.3.2.5.6 Apex/Dry Lake Route Occupational and Public Health and Safety

This section addresses potential impacts to occupational and public health and safety from upgrading highways and heavy-haul truck operations on the Apex/Dry Lake route. The impacts of the Apex/Dry Lake intermodal transfer station would be the same as those discussed in Section 6.3.3.1.

Table 6-115. Impacts to workers from industrial hazards from upgrading highways along the Apex/Dry Lake route.

Group and trauma category	Construction[a]	Operations[b]
Involved workers		
Total recordable cases[c]	22	120
Lost workday cases	11	66
Fatalities	0.03	0.33
Noninvolved workers[d]		
Total recordable cases	1.3	6.8
Lost workday cases	0.5	2.5
Fatalities	0.001	0.007
Totals[e]		
Total recordable cases	23	130
Lost workday cases	11	68
Fatalities	0.032	0.34

a. Impacts are totals over about 28 months.
b. Includes periodic maintenance and resurfacing. Impacts are totals over about 24 years.
c. Total recordable cases includes injury and illness.
d. The noninvolved worker impacts are based on 25 percent of the involved worker level of effort.
e. Totals might differ from sums due to rounding.

Highway Construction and Upgrades. Industrial safety impacts on workers from upgrading highways for the Apex/Dry Lake route would be small (see Table 6-115). The analysis evaluated the potential for impacts in terms of total reportable cases of injury, lost workday cases, fatalities for workers, and traffic fatalities related to commuting workers and the movement of construction materials and equipment. Table 6-116 lists the estimated fatalities from construction and commuter vehicle traffic.

Operations. Incident-free radiological impacts listed in Table 6-117 would occur during the routine transportation of spent nuclear fuel and high-level radioactive waste on the route. These impacts would include transportation along the route as well as transportation along railways in Nevada leading to an Apex/Dry Lake intermodal transfer station. The table includes the impacts of 1,079 legal-weight truck shipments from commercial sites that do not have the capability to load rail casks while operational.

Table 6-116. Estimated number of fatalities from construction material delivery vehicles and construction and operations worker commuting traffic for the Apex/Dry Lake route for heavy-haul trucks.[a]

Activity	Kilometers[b]	Traffic fatalities	Vehicle emissions fatalities
Construction[c]			
Material delivery vehicles	15,000,000	0.3	0.03
Commuting workers	20,000,000	0.2	0.03
Subtotals	*35,000,000*	*0.5*	*0.06*
Operations[d]			
Commuting workers	120,000,000	1.2	0.16
Totals	***160,000,000***	***1.7***	***0.22***

a. Includes impacts of construction and operation of an intermodal transfer station.
b. To convert kilometers to miles, multiply by 0.62137.
c. Impacts are totals over about 28 months.
d. Impacts are totals over 24 years.

Table 6-117. Health impacts[a] from incident-free Nevada transportation for the Apex/Dry Lake heavy-haul truck implementing alternative.

Category	Legal-weight truck shipments	Rail and heavy-haul truck shipments[b]	Totals[c]
Involved workers			
Collective dose (person-rem)	38	1,100	1,100
Estimated latent cancer fatalities	0.02	0.44	0.46
Public			
Collective dose (person-rem)	7	150	160
Estimated latent cancer fatalities	0.003	0.08	0.08
Estimated vehicle emission-related fatalities	0.002	0.064	0.066

a. Impacts are totals for 24 years.
b. Includes impacts to workers at an intermodal transfer station.
c. Totals might differ from sums of values due to rounding.

6.3.3.2.5.7 Apex/Dry Lake Route Socioeconomics

This section describes potential socioeconomic impacts that would occur from upgrading highways along an Apex/Dry Lake route, advancing the construction schedule for a section of the planned Las Vegas Beltway to accommodate heavy-haul trucks, and building an intermodal transfer station. The section also describes socioeconomic impacts from the operation of an intermodal transfer station in Clark County and the periodic resurfacing of highways.

This analysis of economic measures assumed that Clark County would secure a loan to advance the construction schedule of the section of the Las Vegas Beltway that would be part of this heavy-haul truck route. The analysis based the estimates for a range of impacts on two sources of information from Clark County about the cost of building a section of the Beltway. Modifications to the Beltway would cost between $40 million (DIRS 103710-Clark County 1997, p. 2-7) and $425 million in 1998 dollars (DIRS 155112-Berger Group 2000, p. 29) (about $43.6 million to $463 million in 2001 dollars). DOE believes the actual cost would be between these values. A loan to Clark County for $43.6 million or $463 million, at an annual rate of 3 percent, with the repayment of the loan starting in 2010 and lasting for 30 years, is a part of the modeling to determine the impacts to employment, population, real disposable income, and expenditures by State and local governments. (A *real* percentage rate is the premium paid in addition to the rate of inflation; a real rate plus the rate of inflation equals the nominal or quoted rate.) Clark County would repay the loan from tax revenues. DOE assumes most repayment funds would be from sources the county has already identified for completion of the Beltway.

Highway Construction and Upgrades. Socioeconomic impacts from upgrading highways for an Apex/ Dry Lake route, advancing the schedule for construction of a portion of the Las Vegas Beltway, and building an intermodal transfer station would be temporary, occurring over a short period and spread among the counties along the route. The highway upgrades, excluding the Beltway, would cost $20.8 million, require about 28 months to complete, and occur during the 48-month construction period for the Beltway. Building an intermodal transfer station would cost about $25.0 million and take 18 months to complete. If this route was selected, the construction schedule of the planned Las Vegas Beltway would be advanced. (Dollar values reported in this section are 2001 dollars unless otherwise stated.)

This discussion expresses values for socioeconomic measures (employment, population, real disposable income, Gross Regional Product, and State and local government expenditures) and for potential impacts that would change in those measures as a range of values. The first value refers to the outcome if the Beltway cost is $43.6 million; the second refers to the outcome if the Beltway cost is $463 million. DOE anticipates that the actual change would be between the two values.

Employment

Employment in the region of influence of construction workers involved with upgrading the highways (including the Beltway) or with building an intermodal transfer station (direct workers) and other workers who would be employed as a result of the economic activity generated by the project (indirect workers) would peak in 2008. Employment increases would be between 490 and 1,882 jobs. The increase in employment in Clark County would be between 482 and 1,848 workers, Nye County would gain between 6 and 27 workers, and Lincoln County would gain between 1 and 5 workers. The increases in Clark, Nye, and Lincoln Counties would be less than 1 percent of the employment baseline for each county.

Population

The increase in employment would also bring population increases in the region of influence that would peak in 2009. During that year, the incremental increase in population would be between 356 and 1,857 individuals. Clark County would experience about 97 percent of this impact. The increase in population for Clark County would be between 347 and 1,812, for Lincoln County between 0 and 5, and for Nye County between 7 and 39. The impact from an increase in population as a result of increased employment opportunities would be less than 1 percent of each county's population baseline. Because the increases in population in each county would be small and transient, impacts to schools or housing would be unlikely.

Economic Measures

Economic measures would rise during the construction of an intermodal transfer station and the upgrading of highways and Las Vegas Beltway. The increase in real disposable income of people in the three-county region of influence would peak in 2008 at between $15.7 million and $62.0 million. The region-wide increase in Gross Regional Product would peak in 2008 at between $28.9 million and $99.8 million. Increased State and local government expenditures would peak in 2009 at between $1.2 million and $6.1 million. More than 97 percent of this economic activity would be concentrated in Clark County. The Gross Regional Product, real disposable income, and expenditures by State and local governments would rise by less than 1 percent in Clark, Nye, and Lincoln Counties. (All dollar values reported in this section are in 2001 dollars unless otherwise stated.)

Transition to Operations. In the region of influence, employment of Apex/Dry Lake heavy-haul truck route workers and indirect (support) workers would decrease by 419 to 2,026 when construction of the intermodal transfer station and highway upgrades (including the Beltway portion) ended in 2009. Clark County would lose between 412 and 1,993 of these jobs, Nye County would lose between 6 and 28 of these jobs, and Lincoln County would lose between 1 and 5 jobs. DOE anticipates that some of the displaced workers would move into operational positions on the Apex/Dry Lake route while others would find other work in the State. While this project would lose jobs, employment projections for the State estimate approximately 1.4 million jobs in 2010, or about 999,500 in the region of influence.

Operations. Operations at an intermodal transfer station and the use of heavy-haul trucks would begin in 2010 and continue until 2033. A direct workforce of about 26 would be required for the intermodal transfer station. Direct employment for heavy-haul truck operations over an Apex/Dry Lake route, including Clark County-based shipment escorts, would be about 66 workers. DOE assumed that operations workers would reside in Clark County.

To analyze the socioeconomic impacts of operations for an Apex/Dry Lake route, DOE considered three activities: operation of the intermodal transfer station, operation of the heavy-haul trucks, and maintenance of the highways and the Las Vegas Beltway.

Employment and Population

Employment in the region of influence associated with the operations of an intermodal transfer station and heavy-haul trucks would average about 99 workers, all of whom would work in Clark County. The impact on population from these two activities would be an average of 129 workers of whom 127 would live in Clark County. These impacts to employment and population would be less than 1 percent of the baseline in Clark County. During periodic road resurfacing, employment (direct and indirect) in the region would increase by about 107 workers for 2 years. DOE assumed that all of these workers would come from Clark County-based firms. Overall, employment increases from periodic highway resurfacing projects (every 8 years starting in 2016) would be less than 1 percent of the baseline for Clark County. Given the short duration of each resurfacing project, there would be no perceptible change in the region's population.

Net changes to employment and population from all three portions of the Apex/Dry Lake heavy-haul truck route during the 24-year operations phase can be summarized. There would be an incremental increase of 90 positions in the region of influence, with 89 of the additional positions in Clark County if the cost of the beltway was approximately $43.6 million. The region of influence would experience a growth in population of an additional 137 residents, 132 of them in Clark County. This impact would be less than 1 percent of the baseline. If the cost of the beltway reaches $463 million, the region of influence (while continuing to grow to an average of 1.1 million jobs), would have 242 fewer employment positions, with 241 of these in Clark County. Population, which is driven by employment, would be affected. The region of influence would have 511 fewer residents and Clark County would have 519 fewer residents. The impacts at the upper range of the cost estimates would be less than 1 percent of the baselines. Because the impacts would be so small, impacts to housing or schools would be unlikely.

Economic Measures

Impacts from changes to the economic measures of real disposable income, Gross Regional Product, and expenditures by State and local governments from operating an intermodal transfer station at Apex/Dry Lake, operating heavy-haul trucks, and maintaining the highways would fluctuate throughout the operations period and would depend partially on changes in population and employment. If the beltway cost was at the lower end of the cost estimate, real disposable income and Gross Regional Product in the region of influence would rise during the operations period. The increase in real disposable income would average $3.6 million and in Gross Regional Product would average $8.2 million. Expenditures by governments would increase over the 24-year period by an average of $479,000. Virtually all of the activity would be concentrated in Clark County and would be less than 1 percent of the various baselines. If the final cost of the beltway was $463 million, the impacts would be more visible but still less than 1 percent of the applicable baselines. Real disposable income would decline from $4.0 million above the baseline in 2010 to $35.6 million below the baseline by 2033, an average of slowing growth in this area of $29.2 million. The region of influence would have an average real disposable income of $55,797,000 during this period. Gross Regional Product would remain below the baseline, averaging $11.2 million annually. Expenditures by government would decline from $5.4 million above the baseline in 2010 to $4.5 million below the baseline in 2033. The average would be a slowing of spending by $1.9 million. As population growth slows, there would be a slowing in the rate of tax revenues collected and a slowing in the rate of population growth that would require a given level of services.

6.3.3.2.5.8 Apex/Dry Lake Route Noise and Vibration

Section 6.3.3.1 discusses noise impacts common to all the heavy-haul truck implementing alternatives. This section focuses on noise impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Highway Construction and Upgrades. There is one residence near the Dry Lake site of the three tracts of land identified for an intermodal transfer station. Construction noise would occur during daylight hours and would be a temporary source of elevated noise in the area. Nighttime noise impacts would be unlikely because construction activities would not occur at night.

For the Apex/Dry Lake route, northern Las Vegas, the Town of Indian Springs, and the rural community of Cactus Springs are within the 2,000-meter (6,600-foot) region of influence for construction noise. Construction activities would occur at the I-15 interchange at Apex and along sections of U.S. 95. The route, which passes north of Las Vegas, is not heavily populated and the potential for noise-related construction impacts would be low.

Operations. An Apex/Dry Lake intermodal transfer station would be isolated, with one residence (DIRS 155825-Poston 2001, all) in the vicinity, adjacent to an existing rail line. The potential for noise impacts is unlikely unless operations were close to this residence.

The Apex/Dry Lake route would be confined to established highways with wide shoulders. Background traffic noise levels would be greatest along the planned northern Beltway, reducing the potential for heavy-haul truck noise to affect public receptors adversely during daylight hours. The incremental noise increase due to the infrequent heavy-haul truck shipments would not alter the existing noise environment. Estimated noise levels (1-hour average sound levels) at Indian Springs and Cactus Springs would increase by about 0.4 dBA [at 15 meters (44 feet) from the road] due to heavy-haul truck traffic. A potential receptor is the public school in Indian Springs, which also serves students from Cactus Springs. The Indian Springs school is about 300 meters (980 feet) south of U.S. 95. The incremental contribution of heavy-haul trucks at this distance from the highway would not be perceptible. No historic buildings would be affected by ground vibration. No sensitive ruins of cultural significance have been identified along this route.

The Apex/Dry Lake intermodal transfer station is about 3 kilometers (2 miles) from the Moapa Reservation. Assuming that the greatest source of noise would be locomotives, estimated noise levels at 520 meters (1,700 feet) would be 45 dBA. Noise generated at the intermodal transfer station would not be perceptible 910 meters (3,000 feet) away at the border of the Moapa Reservation. The Apex/Dry Lake heavy-haul truck route on U.S. 95 also passes through about 1.6 kilometers (1 mile) of the Las Vegas Paiute Reservation. Because of the relatively large traffic volume on U.S. 95, the increase in traffic noise due to heavy-haul trucks in this area would not be perceptible (DIRS 155825-Poston 2001, all).

6.3.3.2.5.9 Apex/Dry Lake Route Utilities, Energy, and Materials

Section 6.3.3.1 discusses the utilities, energy, and materials impacts that would be common to all the heavy-haul truck implementing alternatives. This section focuses on the utilities, energy and materials impacts that would be unique to the Apex/Dry Lake heavy-haul truck implementing alternative.

Highway Construction and Upgrades. The construction of the Apex/Dry Lake intermodal transfer station would have the same utilities, energy, and materials impacts as those discussed in Section 6.3.3.1.

Table 6-118 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Apex/Dry Lake route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

Table 6-118. Utilities, energy, and materials required for upgrades along the Apex/Dry Lake route.

Route	Length (kilometers)[a]	Diesel fuel (million liters)[b]	Gasoline (thousand liters)	Asphalt (million metric tons)[c]	Concrete (thousand metric tons)	Steel[d] (metric tons)
Apex/Dry Lake	182	1.6	29	0.23	0.1	2.3

a. To convert kilometers to miles, multiply by 0.62137.
b. To convert liters to gallons, multiply by 0.26418.
c. To convert metric tons to tons, multiply by 1.1023.
d. Steel includes rebar only.

Operations. Section 6.3.3.1 discusses the utilities, energy, and materials needs for the operation of an intermodal transfer station.

Fossil fuel that would be consumed by heavy-haul trucks during operations is discussed in Chapter 10, which addresses irreversible commitments of resources.

6.3.4 ENVIRONMENTAL JUSTICE IMPACTS IN NEVADA

The analysis considered existing highways and railroads that DOE would use in Nevada—I-15, the proposed Las Vegas Beltway; U.S. 95; five possible highway routes for heavy-haul trucks; the Union Pacific Railroad's mainlines in northern and southern Nevada; and five corridors with variations for a possible branch rail line in the State. If DOE constructed and operated the repository, it would use combinations of these routes for shipments of spent nuclear fuel and high-level radioactive waste. DOE would use alternative preferred routes designated by the State of Nevada for highway shipments to the repository.

In general, the consequences of using a transportation route would occur close to the route. Thus, for transportation on a highway or railroad to affect a census block group for which environmental justice concerns could exist, the route would have to cross or be adjacent to the block group. Chapter 3, Section 3.1.13 discusses and depicts the minority and low-income populations in Nevada.

Portions of some routes would cross or be adjacent to Native American tribal lands. Existing or proposed highway routes avoid census block groups with high fractions of minority, low-income, or Native American populations with the exceptions of:

- Sections of I-15 that pass through the center of the Moapa Reservation northeast of Las Vegas, Nevada
- A 1.6-kilometer (1-mile) section of U.S. 95 across the southwest corner of the Las Vegas Paiute Indian Reservation that could be used by legal-weight trucks as well as either the Caliente/Las Vegas or Apex/Dry Lake heavy-haul truck route
- The Caliente/Las Vegas and Apex/Dry Lake routes for heavy-haul trucks, which would pass near the Moapa Reservation
- Sparsely populated areas of census block groups in the northern parts of Clark County

Table 6-118 lists the estimated quantities of primary materials for the upgrade of Nevada highways for the Apex/Dry Lake route. These quantities are not likely to be very large in relation to the southern Nevada regional supply capacity (see Section 6.3.3.1).

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- The Caliente/Las Vegas and Apex/Dry Lake routes for heavy-haul trucks, which would pass near the Moapa Reservation
- Sparsely populated areas of census block groups in the northern parts of Clark County

Existing or proposed rail routes could cross census block groups with high populations of minority, low-income, or populations of Native Americans only at the following points:

- The Union Pacific Railroad's mainline tracks pass through the center of the Moapa Reservation and through the center of Las Vegas, Nevada, crossing census block groups with high fractions of minority and low-income populations.

- The Bonnie Claire Alternate of the Caliente and Carlin Corridors would pass through 4.5 kilometers (2.8 miles) covering 1.8 square kilometers (450 acres) of the Scottys Junction portion of the newly designated Timbisha Shoshone Trust Lands parcel planned for residential use and tourist-related business.

Also, a branch rail line in the Valley Modified Corridor would pass near the Las Vegas Paiute Reservation. None of the potential intermodal transfer station sites that DOE could use would be near a census block group with high minority or low-income populations, but an intermodal transfer station in the Apex/Dry Lake area could be as close as about 3 kilometers (2 miles) to the Moapa Reservation.

Impacts to resource areas other than environmental justice along Nevada highways and railroads from the transportation of spent nuclear fuel and high-level radioactive waste would be small. The number of shipments in the mostly legal-weight truck and mostly rail scenarios would be small in comparison to the number of all other commercial shipments in southern Nevada. For comparison, under the mostly legal-weight truck scenario as many as five trucks carrying spent nuclear fuel would pass through the Moapa Indian Reservation on I-15 each day compared to daily traffic of more than 3,000 commercial trucks that use this section of highway (DIRS 156930-NDOT 2001, p. 6; DIRS 104727-Cerocke 1998, all). Under the mostly rail scenario as many as 11 railcars per week carrying spent nuclear fuel could travel into southern Nevada compared to about 1,000 railcars each day for other commodities. Thus, impacts from truck and rail traffic and emissions would be small for these shipments. The potential for accidents that could result in injuries or fatalities involving the shipments would also be small in comparison to the overall risk of accidents that would occur from other commercial traffic.

As much as 10 percent of travel in southern Nevada by legal-weight trucks or railcars carrying spent nuclear fuel would be through populations of Native Americans and census block groups with high fractions of minorities or low-income populations, depending on the selected route and transportation mode. Public health and safety impacts to all populations in Nevada would be small (about 1 fatality from cancer and other causes for incident-free transportation and 0.00006 latent cancer fatality for accidents over 24 years).

The public health and safety impacts to minority and low-income populations along the routes of travel would also be small. Because the probability would be small at any single location, the risk of an accident at a specific location would also be small. Thus, impacts to minority or low-income populations or to populations of Native Americans in small communities along the routes would also be small and, therefore, unlikely to be disproportionately high and adverse.

Unique practices and activities could create opportunities for increased impacts from transportation of spent nuclear fuel and high-level radioactive waste associated with the Proposed Action. One such practice could be the use of subsistence diets (that is, consumption of homegrown or naturally available plant and animal food). Because no radioactive materials would be released to the environment during incident-free transportation, the implementation of new or existing transportation routes in Nevada would not affect food sources likely to be involved in subsistence diets. If an accident resulted in the release of radioactive materials, food sources, both agricultural and subsistence, could be affected and mitigative actions would have to be taken to prevent contamination or consumption of contaminated food.

The American Indian Writers Subgroup identified noise from transportation as a concern because of its effects on ceremonies and the solitude necessary for healing and praying (DIRS 102043-AIWS 1998, p. 2-19). DOE is not aware of traditional cultural properties or other areas along the candidate rail corridors or routes for heavy-haul trucks, including variations, where noise from trains, construction of a branch rail line or intermodal transfer station, or conduct of heavy-haul or other trucking operations could interfere with conditions necessary for meditation by, or religious ceremonies of, Native Americans, with the exception of the Caliente Intermodal Transfer Station, as noted below. Similarly, no known ruins or other culturally sensitive structures have been identified that could be affected by ground vibration.

The analysis of transportation-related construction or upgrades identified potentially adverse impacts pertaining to certain routes or transportation modes. DOE could lessen some of these impacts through mitigation, as discussed in Chapter 9. Adverse impacts could include the following:

- The Valley Modified Corridor and some of its variations would involve construction in the Las Vegas Valley air basin, which is in serious nonattainment for particulate matter (PM_{10}) and carbon monoxide (DIRS 155557-Clark County 2001, Tables 3-8 and 5-3). Emission rates would exceed the General Conformity threshold (established by Environmental Protection Agency regulations that implement the Clean Air Act) for PM_{10} for a serious nonattainment area and would qualify the construction as a major source of emissions when evaluated under the Prevention of Significant Deterioration threshold. Comparison of this corridor with known locations of minority and low-income populations indicates that effects on such populations would not be disproportionately high and adverse in comparison with effects on the rest of the population. No unique practices or pathways have been identified that would increase impacts to minority or low-income populations. PM_{10} and carbon monoxide emissions are susceptible to mitigation.

- The northernmost site for a Sloan/Jean intermodal transfer station is in a PM_{10} nonattainment area. Emission rates would exceed the PM_{10} General Conformity threshold for a serious nonattainment area. Comparison of the Sloan/Jean route with known locations of minority and low-income populations indicates that effects on such populations would not be disproportionately high and adverse in comparison with effects on the rest of the population. No unique practices or pathways have been identified that would increase impacts to minority or low-income populations. PM_{10} and carbon monoxide emissions are susceptible to mitigation.

- Most of the road upgrades for a Sloan/Jean heavy-haul truck route would occur in areas that are in attainment for criteria pollutants. However, portions of the upgrades would occur in the Las Vegas Valley air basin, which is in nonattainment for carbon monoxide and PM_{10}. Comparison of the route with known locations of minority and low-income populations indicates that effects from road upgrades on such populations would not be disproportionately high and adverse in comparison with effects on the rest of the population. No unique practices or pathways have been identified that would increase impacts to minority or low-income populations. PM_{10} and carbon monoxide emissions are susceptible to mitigation.

- Construction and operation of a Caliente intermodal transfer station could cause aesthetic impacts to users of Kershaw-Ryan State Park. Impacts could result from construction activities and from noise, traffic, and lighting during operations. Impacts would be similar for all park users and, therefore, would not be disproportionately high and adverse for members of minority or low-income populations. Some of these impacts would be susceptible to mitigation.

- Biology and soils impacts from construction and from corridor and route occupancy and use would include long-term vegetation disturbance in corridors or at an intermodal transfer station and stopover sites. Short-term or individual impacts to threatened and endangered and special-status species could occur. The Valley Modified Corridor crosses two wilderness study areas and a national wildlife refuge. DOE has found no location-related or unique practices and pathways information to indicate that effects on minority or low-income populations would be disproportionately high and adverse in comparison with effects on the rest of the population.

- The construction and operation of a branch rail line in the Caliente or Carlin Corridor along the Bonnie Claire Alternate would cross the Scottys Junction parcel of the Timbisha Shoshone Trust Lands. Sections 6.3.2.2.1 and 6.3.2.2.2 discuss land-use and noise consequences for potential residents. Information available to DOE indicates that the Timbisha Shoshone have not developed residential areas on the parcel. Because residential development of the parcel has not occurred, there is no population present, no way to measure the likelihood of disproportionately high and adverse impacts on a possible minority or low-income population, and no present data indicating a potential for environmental justice concerns from the Bonnie Claire Alternate.

- The construction and operation of a branch rail line in any of the candidate rail corridors could present the potential for direct and indirect impacts to archaeological and historic resources related to Native American culture. Additional archaeological surveys and ethnographic studies are needed for the placement of an alignment within any of the rail corridors, including variations, to determine specific potential impacts and mitigation needs. Records searches indicate that only a small percentage of potentially affected lands in designated rights-of-way have been inspected.

- The operation of a heavy-haul truck route along any of the candidate routes could present the potential for direct and indirect impacts to archaeological and historic resources related to Native American culture. The determination of the potential for impacts to Native American cultural values from the upgrading and use of Nevada highways for heavy-haul truck shipments would require more study. The American Indian Writers Subgroup has commented that ethnographic field studies would be necessary to determine specific potential impacts to Native American cultural properties and values (DIRS 102043-AIWS 1998, p. 4-6) for candidate rail corridors and the use of existing highways as routes for heavy-haul trucks to Yucca Mountain.

- Construction of a Carlin branch rail line could affect two known historic-period Native American cemeteries, one in Crescent Valley and the other in Grass Valley (DIRS 155826-Nickens and Hartwell 2001, p. 27).

- Several rail corridors and routes for heavy-haul trucks pass through or are proximate to significant places for Native Americans. For example, in the Pahranagat National Wildlife Refuge, the Black Canyon area, the Storied Rocks site farther south, and the Maynard Lake vicinity have been identified. The entire Pahranagat Valley is an important cultural landscape (DIRS 155826 Nickens and Hartwell 2001, Appendix A). The Coyote Springs area and the Arrow Canyon Range valley south of the Pahranagat Valley are places of cultural importance. The operation of a Caliente intermodal transfer station could have a lasting impact on the cultural integrity of the location, which Native Americans have identified as an important place. The overall significance of such places and the potential for impacts from the transportation of spent nuclear fuel and high-level radioactive waste cannot be fully understood until a rail alignment or heavy-haul truck route is identified and ethnographic field studies and consultation have been completed.

In the viewpoint of Native Americans, the construction and operation of a branch rail line would constitute an intrusion on the holy lands of the Southern Paiute and Western Shoshone. In addition, some corridors pass through or near several significant places (see Chapter 3, Section 3.2.2.1.5). The American Indian Writers Subgroup has commented that the overall significance of these places and potential impacts from operation of a rail line on them cannot be fully understood until DOE has identified the rail alignment and completed ethnographic field studies and consultations (DIRS 102043-AIWS 1998, p. 4-6). If DOE selected a rail corridor, it would initiate additional engineering and environmental studies (including cultural resource surveys), conduct consultations with Federal agencies, the State of Nevada, and tribal governments, and perform additional National Environmental Policy Act reviews as a basis for final alignment selection and construction. DOE would address the mitigation of potential impacts to archaeological and historic sites during the identification, evaluation, and treatment planning phases of the cultural resource surveys.

For existing highways and mainline railroads, the added traffic would be minimal and shipments of spent nuclear fuel and high-level radioactive waste would be unlikely to affect land use, air quality, hydrology, biological resources and soils, cultural resources, socioeconomics, noise and vibration, or aesthetics, except as noted above. The analyses discussed in the preceding sections also determined that impacts to these resource areas from construction and operation of a branch rail line in any of the five potential rail corridors or construction of an intermodal transfer station and upgrading of highways in Nevada would be low.

Because the analyses did not identify large impacts for railroad and highway transportation of spent nuclear fuel and high-level radioactive waste in Nevada that would constitute credible adverse impacts on populations, workers, or individuals, adverse effects would be unlikely for any specific segment of the population, including minorities, low-income groups, and Native American tribes, except as noted above. Chapter 4, Section 4.1.13.4, contains an environmental justice discussion of a Native American perspective on the Proposed Action.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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7. ENVIRONMENTAL IMPACTS OF THE NO-ACTION ALTERNATIVE

This chapter describes the potential impacts associated with the No-Action Alternative described in Chapter 2. Under the No-Action Alternative and consistent with the Nuclear Waste Policy Act, as amended [NWPA, Section 113(c)(3)], the U.S. Department of Energy (DOE) would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. Commercial utilities and DOE would continue to manage spent nuclear fuel and high-level radioactive waste at 77 sites in the United States.

DOE analyzed the No-Action Alternative to serve as a basis for comparing the magnitude of potential environmental impacts in the Proposed Action. Under the No-Action Alternative, and consistent with the NWPA, DOE would terminate activities at Yucca Mountain and undertake site reclamation to mitigate any significant adverse environmental impacts. In addition, DOE would prepare a report to Congress, with its recommendations for further action to ensure the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste, including the need for new legislative authority. Under any future course that would include continued storage at the generator sites, commercial utilities and DOE would have to continue managing spent nuclear fuel and high-level radioactive waste in a manner that protected public health and safety and the environment. However, the future course that Congress, DOE, and the commercial utilities would take if Yucca Mountain were not approved is uncertain.

DOE recognizes that a number of possibilities could be pursued, including continued storage of spent nuclear fuel and high-level radioactive waste at its present location, or at one or more centralized location(s); the study and selection of another location for a deep geologic repository (Chapter 1 identifies the process and alternative sites previously selected by DOE for technical study as potential geologic repository locations); the development of new technologies (for example, transmutation); or reconsideration of alternatives to geologic disposal (as discussed in Chapter 2, Section 2.3.1). The environmental considerations of these possibilities have been analyzed in other contexts in other documents to varying degrees. DOE also recognizes that under the No-Action Alternative, there would be an increased probability of shutdown of operating reactors before operating license expiration due to the lack of adequate spent nuclear fuel storage capacity, with an attendant loss of electric power generation for that area or region. While the Department recognizes that many environmental impacts could result from shutting down nuclear power reactors, a full evaluation of such impacts (such as generation of additional air pollution from replacement sources of electricity) would be highly speculative because the choice of a replacement power source (importation, solar, gas, coal, etc.) would be regionally dependent, and the affected utilities would make the ultimate decision. Because the determination of local and regional impacts resulting from the loss of electric generating capacity for shutdown reactors, including the potential for increased electricity prices, would be speculative, the EIS does not include a detailed discussion.

Table 7-1 lists representative studies related specifically to centralized or regionalized interim storage, including alternatives evaluated in DOE National Environmental Policy Act documents, and summarizes the relevant environmental considerations. Those studies contain more information on the potential environmental impacts of centralized or regional interim storage.

In light of these uncertainties, DOE decided to illustrate the possibilities by focusing the analysis of the No-Action Alternative on the potential impacts of two scenarios—long-term storage of spent nuclear fuel and high-level radioactive waste at the current sites with effective institutional control for at least 10,000 years (Scenario 1), and long-term storage with no effective institutional control after about 100 years (Scenario 2). Although the Department agrees that neither of these scenarios is likely, it selected them for analysis because they provide a basis for comparison to the impacts of the Proposed Action and because they reflect a range of the impacts that could occur.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 1 of 5).

Title and scope of storage analysis	Environmental and other considerations
Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste (DIRS 104832-DOE 1980, all)	
Evaluates a proposal to provide interim storage of spent nuclear fuel from U.S. power reactors before final disposal. The proposal would include acceptance of a limited amount of foreign spent fuel if such actions would contribute to U.S. nonproliferation goals. Evaluates several generic interim storage facility alternatives, including centralized storage at a few large ISFS facilities.	Analyses include a description of a *generic interim storage site environment* based primarily on data for the midwestern United States, and potential environmental effects of such a facility for ISFS facilities. Impacts evaluated include: natural resources, radiological impacts, land use, water use, ecological resources, air quality, traffic, noise, socioeconomics, waste management, utilities, aesthetics, transportation (including both to ISFS facilities and from ISFS facilities to the disposition facility), and safeguards and security.
Recommendations on the Proposed Monitored Retrievable Storage Facility (DIRS 103173-Clinch River 1985, all)	
Evaluates DOE proposal to consider the Clinch River Breeder Reactor and ORR sites in Tennessee for an MRS facility. Performed by the Clinch River MRS Task Force, which included three study groups: environmental, socioeconomic, and transportation. Public meetings and site visits were conducted by the study groups. Separate reports by each study group are summarized in findings, concerns, anticipated impacts, and recommended mitigations.	The Environmental Study Group's final report presented concerns and recommended mitigations for MRS construction impacts, damage to ecosystem from construction, special nuclear risks of construction, highway construction impacts, radiation protection of workers and the public, airborne effluents, aqueous releases, hazards from cask rupture, earthquakes, flooding, long-term radionuclide containment, secondary waste stream, local control, offsite emergency response, past contamination of the ORR, environmental data from the ORR, and MRS becoming a permanent waste storage site. The Socioeconomic Study Group's final report identified concerns or potentially negative impacts of an MRS and possible mitigations for business recruitment and expansion, residential recruitment and retention, institutional trust, pre- and postoperational impacts and costs, tourism and aesthetics, site neighbors, and legislative issues. The Transportation Study Group's final report defined areas of potential major impacts (for example, independent inspections, upgrades of railroad tracks, routing and upgrades to preferred highway truck routes, escorts, emergency response plans and training, and requirements applicable to private carriers), and presented findings and recommendations on accident probabilities, barge transport, cask safety and contents, prenotification, and safeguards.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 2 of 5).

Title and scope of storage analysis	Environmental and other considerations
Monitored Retrievable Storage Submission to Congress, Volume 2: Environmental Assessment for a Monitored Retrievable Storage Facility (DIRS 104731-DOE 1986, Volume 2, all)	
Evaluates a proposal for the construction of a facility for monitored retrievable storage. Evaluates two facility design concepts at each of three candidate sites in Tennessee (Clinch River Breeder Reactor, ORR, and TVA Hartsville Nuclear Power Plant).	Evaluates impacts common to all three sites and unique to each site, including radiological, air quality, water quality and use, ecological resources, land use, socioeconomics, resource requirements, aesthetics, and transportation. Also evaluates relative advantages and disadvantages of the six site design combinations.
MRS System Study Summary Report (DIRS 104838-DOE 1989, all)	
Evaluates the role of the MRS facility in the waste management system.	Provides additional support to the general conclusion that an MRS facility provides tangible benefits to a waste management system, as articulated in the DOE 1986 MRS proposal to Congress (DIRS 104731-DOE 1986, Volume 2, all). Examines various system configurations in a series of separate publications: • Scenario development and system logistics • Facility design/schedule/cost implications • Alternative MRS storage concepts • Location of high-level radioactive waste packaging • Waste package designs • Transportation impact analyses • Role of waste storage in operations of the waste management system • Licensing impacts of an MRS facility • System reliability
Nuclear Waste Management Systems Issues Related to Transportation Cask Design: At-Reactor Spent Fuel Storage, Monitored Retrievable Storage and Modal Mix (DIRS 104889-Hoskins 1990, all)	
Provides the State of Nevada evaluation of the DOE MRS proposal and the Tennessee studies and position in response.	Addresses the DOE MRS proposal, which evaluated the option of implementing an integral MRS facility as part of a waste management system and the option of “no-MRS facility” as part of the waste management system. The criteria for the evaluation included health and safety, economic, environmental, political (for example, acceptability, public confidence, local and state attitudes), social (for example, fears and anxieties), fairness (for example, equity, intergenerational, utilities/ratepayer, liability, geographic, interutility, and government-utility), repository scheduling, and flexibility (technical and institutional factors).

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 3 of 5).

Title and scope of storage analysis	Environmental and other considerations
Department of Energy Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (DIRS 101802-DOE 1995, all)	
Analyzes transportation and centralized interim storage of existing and projected inventories of DOE spent nuclear fuel (including naval spent nuclear fuel) at one site. Considers five interim storage sites (Hanford, INEEL, ORR, SRS, and the Nevada Test Site).	Focuses on key discriminator disciplines at each of the five sites, including socioeconomics, utilities (electricity), materials and waste management, occupational and public health and safety (radiation effects and accidents), transportation, and uncertainties and conservatism. Discusses cumulative impacts and impacts of no action. Does not provide detailed discussions of land use, cultural resources, aesthetic/scenic resources, geologic resources, air quality, water resources, ecological resources, noise, and utilities and energy because there would be small impacts for these areas that would be indistinguishable among the alternatives.
Final Environmental Impact Statement on a Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel (DIRS 101812-DOE 1996, all)	
Evaluates a proposal to manage FRR spent nuclear fuel. Evaluates a management alternative for acceptance and management of FRR spent fuel in the United States that includes regionalized storage at SRS, INEEL, Hanford, ORR, and the Nevada Test Site. Basic implementation components of the proposal include policy duration, financing arrangements, amount of FRR spent fuel, location for taking title to FRR spent fuel, marine transport, ports of entry, ground transport, FRR spent fuel management sites, and storage technologies.	Analyzes impacts from policy considerations, marine transport, port activities, ground transport, and fuel management sites. More specifically, for fuel management sites, analyzes impacts for occupational and public health and safety, waste management, cumulative impacts, mitigation measures, and environmental justice. Covers impacts for land use, socioeconomics, cultural resources, aesthetics, scenic resources, geology, water resources, air quality, ecology, noise, utilities and energy, and waste management in general.
Final Waste Management Programmatic Environmental Impact Statement For Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste (DIRS 101816-DOE 1997, all)	
Evaluates programmatic alternatives for managing various DOE wastes including HLW. Regionalized and centralized storage are among the management options evaluated. Under the regionalized alternatives, canisters from West Valley would be transported either to SRS or to Hanford, and HLW canisters would continue to be stored at Hanford, SRS, and INEEL until acceptance at the geologic repository. Under the centralized storage alternative, canisters would be transported from West Valley, INEEL, and SRS to Hanford, where they would be stored until acceptance at a geologic repository.	Describes regionalized and centralized sites based on available site-specific data and existing and planned storage facilities for HLW canisters. Impacts evaluated include health risks (includes transportation), air quality, water resources, ecological resources, economics, population, environmental justice, land use, infrastructure, cultural resources, and costs.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 4 of 5).

Title and scope of storage analysis	Environmental and other considerations
Environmental Report for the Private Fuel Storage Limited Liability Company's (PFS) Proposed Independent Spent Fuel Storage Installation (ISFSI) License Application (DIRS 103436-PFS 1997, all)	
Evaluates the impacts of a privately owned dry fuel storage facility proposed to be built in western Utah on the Skull Valley Goshute Indian Reservation. The facility would receive and store as much as 40,000 MTHM from several commercial nuclear reactor plants. In June of 2000, the NRC published a Draft EIS to support its licensing process for this facility.	Provides detailed descriptions and environmental impact analyses associated with construction and operation of the site and transportation corridors for geography, land use, and demography; ecological resources; climatology and meteorology (including air quality); hydrological resources; mineral resources; seismology; socioeconomics (including environmental justice analysis); noise and traffic; regional historic and cultural resources; scenic and natural resources; background radiological characteristics; and transportation (radiological and nonradiological impacts). Addresses installation siting and design alternatives based on several specific evaluation criteria (geography and demography; ecology; meteorology; hydrology; geology; regional historic/archaeological/architectural/scenic, cultural/natural features; noise; radiological characteristics).
Centralized Interim Storage Facility Topical Safety Analysis Report (DIRS 103375-DOE 1998, all)	
Analyzes an above-ground temporary storage facility for up to 40,000 MTHM of commercial reactor spent nuclear fuel. The non-site-specific analysis concludes that DOE could construct and operate the commercial interim storage facility in a manner that protects public health and safety.	Describes generic site characteristics and design criteria developed to bound, to the extent possible, site-specific values once a CISF is selected. Generic site characteristics include meteorology, surface hydrology, geology, and seismology. Principal design parameters evaluated for normal and accident conditions include type of fuel, storage systems, fuel characteristics, tornado (wind and missile load), straight wind, floods, precipitation, snow and ice, seismicity (ground motion and surface faulting), volcanic eruption (ash fall), explosions, aircraft impact, proximity to uranium fuel cycle operations, ambient temperature, solar load, confinement, radiological protection, nuclear criticality, decommissioning, materials handling, and retrieval capability.

Table 7-1. Documents that address centralized or regionalized storage of spent nuclear fuel and high-level radioactive waste[a] (page 5 of 5).

Title and scope of storage analysis	Environmental and other considerations
Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Shull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, (DIRS 152001-NRC 2000, all)	
Evaluates the impacts of a privately owned dry fuel storage facility proposed to be built in western Utah on the Skull Valley Goshute Indian Reservation. The facility would receive and store as much as 40,000 MTHM from several commercial nuclear reactor plants.	Provides detailed descriptions and environmental impact analyses associated with construction and operation of the site and transportation corridors for geography, land use, and demography; ecological resources; climatology and meteorology (including air quality); hydrological resources; mineral resources; seismology; socioeconomics (including environmental justice analysis); noise and traffic; regional historic and cultural resources; scenic and natural resources; background radiological characteristics; and transportation (radiological and nonradiological impacts). Addresses installation siting and design alternatives based on several specific evaluation criteria (geography and demography; ecology; meteorology; hydrology; geology; regional historic/archaeological/architectural/scenic, cultural/natural features; noise; radiological characteristics). Provides impact analyses for the No-Action Alternative where NRC would not approve the license application to construct and operate the proposed storage facility and utilities would continue to store spent nuclear fuel at their reactor sites until it is shipped to a permanent geological repository.

a. Abbreviations: ISFS = independent spent fuel storage; ORR = Oak Ridge Reservation; MRS = monitored retrievable storage; TVA = Tennessee Valley Authority; INEEL = Idaho National Engineering and Environmental Laboratory; SRS = Savannah River Site; FRR = Foreign Research Reactor; HLW = high-level radioactive waste; MTHM = metric tons of heavy metal; NRC = U.S. Nuclear Regulatory Commission; CISF = centralized interim storage facility.

Chapter 2 describes the scenarios more fully. Appendix K contains detailed descriptions of the assumptions for each scenario. For consistency, the No-Action analysis considered the same spectrum of environmental impacts as the analysis of the Proposed Action. However, because of the DOE commitment to manage spent nuclear fuel and high-level radioactive waste safely and the uncertainties typical in predictions of the outcome of complex physical and biological phenomena over long periods, DOE decided to focus the No-Action analysis on the short- and long-term health and safety of workers and members of the public.

To ensure a consistent comparison with the Proposed Action for the cumulative effects analysis, the analysis included the impacts of the continued storage of spent nuclear fuel and high-level radioactive waste in excess of 70,000 metric tons of heavy metal (MTHM). This additional material, with the 70,000 MTHM under the Proposed Action (collectively called Module 1), includes 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste.

In view of the almost unlimited possible future states of society and the importance of these states to future risk and dose, the National Research Council recommended the use of a particular set of assumptions about the biosphere (for example, how people get their food and water and from where) for compliance calculations such as those performed to evaluate long-term repository performance. Further, the National Research Council recommended the use of assumptions that reflect current technologies and living patterns (DIRS 100018-National Research Council 1995, p. 122). For consistency with the methods used to analyze environmental impacts from the proposed repository, the No-Action analysis selected current technologies and living patterns for the long-term impact evaluation, even though they might not represent an accurate prediction of future conditions.

DEFINITION OF
METRIC TONS OF HEAVY METAL

Quantities of spent nuclear fuel are traditionally expressed in terms of *metric tons of heavy metal* (typically uranium), without the inclusion of other materials such as cladding (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume. One metric ton of heavy metal disposed of as spent nuclear fuel would fill a space approximately the size of a typical household refrigerator.

Under Scenario 1, 77 sites around the country would store spent nuclear fuel and high-level radioactive waste. For this scenario, the analysis assumed that institutional control for at least 10,000 years would ensure regular maintenance and continuous monitoring at the facilities, which would safeguard the health and safety of facility employees, surrounding communities, and the environment. All maintenance, including routine industrial maintenance and maintenance unique to a nuclear materials storage facility, would be performed under standard operating procedures or best management practices to ensure minimal releases of contaminants (industrial and nuclear) to the environment and minimal exposures to workers and the public. With institutional control, the facilities would be maintained to ensure that workers and the public received adequate protection in accordance with current Federal regulations such as 10 CFR Part 20 and Part 835 and DOE Order requirements (see Chapter 11, Tables 11-1, 11-3, and 11-4).

In addition, the Scenario 1 analysis assumed that storage facilities would undergo replacement every 100 years and would undergo major repairs halfway through the first 100-year cycle, because the storage facilities at any site would be built for a facility life of less than 100 years. (Federal regulations [10 CFR 72.42(a)] require license renewal every 20 years.) Figure 7-1 shows facility timelines for Scenarios 1 and 2.

DOE and commercial organizations intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, to provide a basis for evaluating the upper limits of potential adverse human health impacts, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years. Therefore, after about 100 years and up to 10,000 years, the scenario assumes that spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial sites and 5 DOE sites would begin to deteriorate and that the radioactive materials in the spent nuclear fuel and high-level radioactive waste would eventually be released to the environment, contaminating the local soil, surface water, and groundwater. Appendix K contains the details of this long-term analysis.

For this environmental impact statement (EIS), DOE performed analyses to 10,000 years from the present. To parallel the repository analysis, the No-Action analysis considered both short- and long-term impacts. Short-term impacts would be those experienced during about the first 100 years, and long-term impacts would be those experienced during the remaining 9,900 years. Short-term impacts would be the

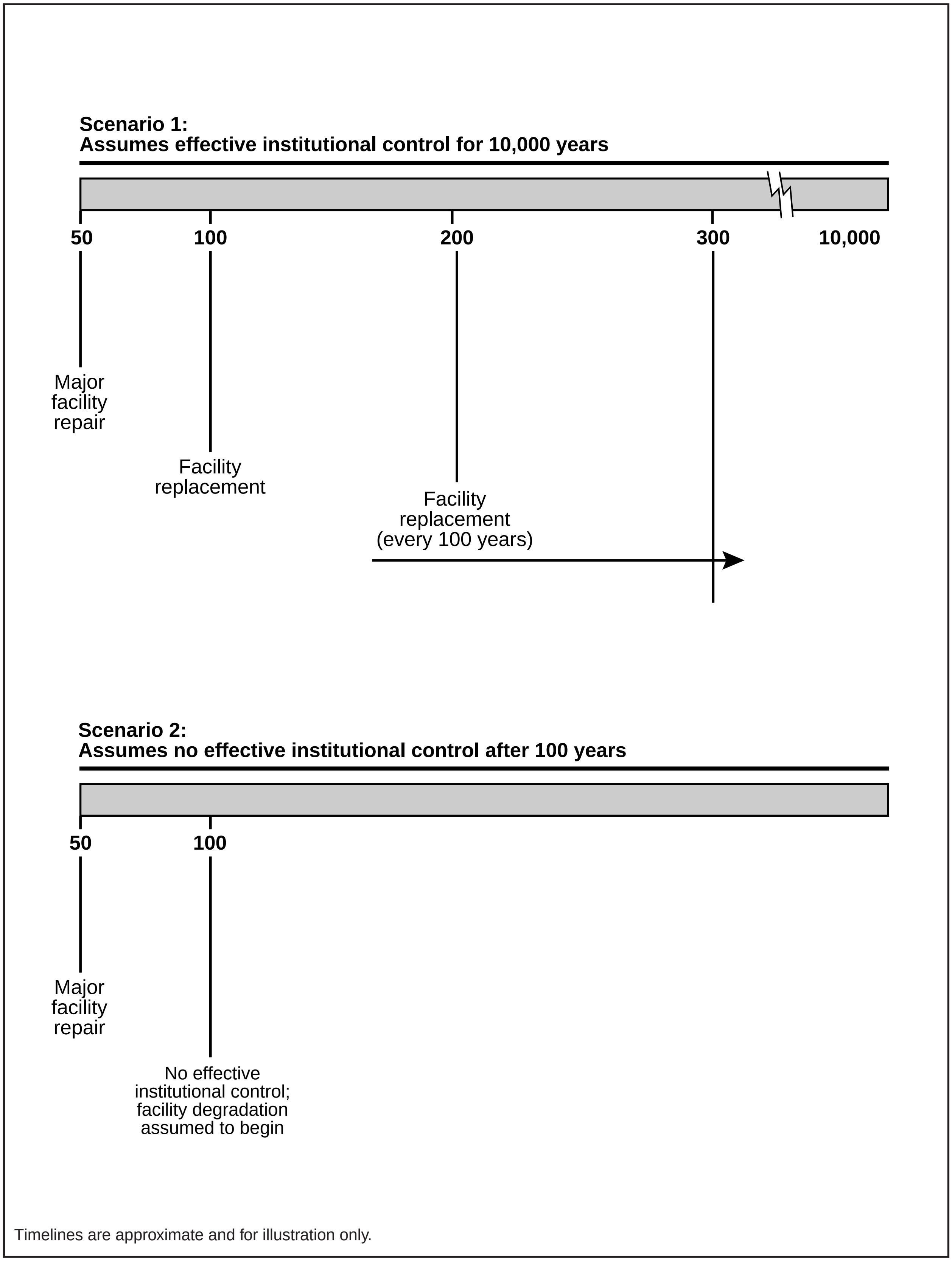

Figure 7-1. Facility timeline assumptions for No-Action Scenarios 1 and 2.

same under Scenarios 1 and 2 because both scenarios assume institutional control during this period. The short-term No-Action Alternative impacts include those resulting from the termination of activities at Yucca Mountain and decommissioning and reclamation of the site, so there would be no long-term impacts at the Yucca Mountain site. In addition, the short-term No-Action Alternative impacts at Yucca Mountain would be the same for both scenarios.

Impacts at the 77 sites after approximately 100 years (long-term) under Scenario 1 primarily would affect facility workers. Long-term impacts at the storage sites after approximately 100 years under Scenario 2 would affect only members of the public because the facility would close and there would be no workers (Scenario 2 assumes no effective institutional control after about 100 years).

To permit a comparison of both short- and long-term impacts from the construction, operation and monitoring, and eventual closure of a proposed repository at Yucca Mountain and from the No-Action Alternative, DOE took care to maintain as much consistency as possible in the methods used to analyze environmental impacts from the proposed repository and the No-Action Alternative. Important consistencies include the following:

- Identical spent nuclear fuel and high-level radioactive waste inventories:
  - Proposed Action: 63,000 metric tons of heavy metal (MTHM) of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, 8,315 canisters of high-level radioactive waste, and surplus weapons-usable plutonium (as mixed-oxide fuel or immobilized plutonium)
  - Module 1: Proposed Action materials plus an additional 42,414 MTHM of commercial spent nuclear fuel, 167 MTHM of DOE spent nuclear fuel, and 13,965 canisters of high-level radioactive waste resulting in a total of 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste.

    This inventory includes surplus plutonium in the form of mixed-oxide fuel or immobilized plutonium (see Appendix A, Figure A-2).
- Identical evaluation periods of 100 years (short-term impacts) and of 100 to 10,000 years (long-term impacts)
- Consistent spent nuclear fuel and high-level radioactive waste corrosion and dissolution models
- Identical radiation dose and risk conversion factors
- Similar assumptions regarding the habits and behaviors of future population groups (that is, they would not be greatly different from those of populations today)

Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would improve long-term repository performance and reduce uncertainty. The result of the design evolution process was the development of the flexible design (DIRS 153849-DOE 2001, all), which was evaluated in the Supplement to the Draft EIS. This design focuses on controlling the temperature of the rock between waste emplacement drifts. As a result of these design changes, this Final EIS evaluates a range of repository operating modes (higher- to lower-temperature). The lower-temperature operating mode has the flexibility to remain open and under *active institutional control* for up to 300 years after emplacement. Although Chapter 4 of this EIS includes an evaluation of impacts for this period, DOE did not evaluate the 300-year institutional control case for the No-Action Alternative. The primary reason for not updating this part of the analysis was because if the institutional control period for the analysis of the No-Action Alternative were extended to 300 years, the short-term environmental impacts would have

INSTITUTIONAL CONTROL

Institutional control implemented by commercial utilities and DOE provides monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements. Having attained this goal, institutional control ensures the maintenance of incurred doses as low as reasonably achievable, taking social and economic factors into account. Because the future course of action taken by the Nation and by commercial utilities would be uncertain if Yucca Mountain were not recommended as a repository site, the continued storage analysis evaluated two hypothetical scenarios with different assumptions about institutional control to bound potential environmental impacts.

The assumption for Scenario 1 is that DOE and commercial utilities would maintain institutional control of the storage facilities to ensure minimal releases of contaminants to the environment for at least 10,000 years.

Scenario 2 assumes no effective institutional control after approximately 100 years. DOE based the choice of 100 years on a review of generally applicable U.S. Environmental Protection Agency regulations for the disposal of spent nuclear fuel and high-level radioactive waste (40 CFR Part 191), U.S. Nuclear Regulatory Commission regulations for the disposal of low-level radioactive material (10 CFR Part 61), and the National Research Council report on standards for the proposed Yucca Mountain Repository (DIRS 100018-National Research Council 1995, p. 106), which generally discount the consideration of institutional control for longer periods in performance assessments for geologic repositories.

increased by as much as 3 times. DOE did not want to appear to overstate the impacts from the No-Action Alternative.

Since the publication of the Draft EIS, DOE modified the spent nuclear fuel cladding corrosion rates and failure mechanisms used in the performance analysis in Chapter 5 of the Final EIS. DOE did not update these models for the No-Action Alternative Scenario 2 analysis because the outcome would have been an increase in the long-term radiation doses and potential health impacts, however, the increase would be within the uncertainties discussed in Appendix K, Section K.4. In addition, the radionuclide inventories for commercial spent nuclear fuel were updated for the Final EIS (see Appendix A, Tables A-8 and A-9) to reflect the higher initial enrichments and burnup projected for commercial nuclear facilities. Although these revised inventories were used to estimate potential short-term repository impacts in the Final EIS (Chapter 4), DOE chose not to update the No-Action inventories because, again, the effect on the outcome would be about a 15-percent increase in health impacts in this chapter.

Affected populations for the No-Action Alternative were, in general, based on 1990 census estimates and not projected to 2035 as was done for the Proposed Action. However, if the population across the Nation had been projected to 2035, the collective impacts resulting from radiation exposure would have increased by less than a factor of 1.5, which is the average expected increase in national population from 1990 to 2035 (DIRS 152471-Bureau of the Census 2000, all).

7.1 Short-Term Impacts in the Yucca Mountain Vicinity

Chapter 3, Section 3.3, discusses the conditions at the sites that formed the basis for identifying potential impacts associated with the No-Action Alternative. The conditions include the relatively small incremental impacts resulting from continued characterization activities in the Yucca Mountain vicinity until 2002. Under the No-Action Alternative, DOE would terminate characterization activities at the site

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The assumption for Scenario 1 is that DOE and commercial utilities would maintain institutional control of the storage facilities to ensure minimal releases of contaminants to the environment for at least 10,000 years.

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The short-term impacts from reclamation of the Yucca Mountain site would occur regardless of the No-Action Alternative scenario and would be the same for both scenarios.

7.1.1 LAND USE AND OWNERSHIP

Land ownership and control could revert to the original controlling authority.

Under the No-Action Alternative, decommissioning and reclamation would begin as soon as practicable at the Yucca Mountain site, which DOE anticipates would happen in 2002. No new land would be required to support the decommissioning and reclamation activities. Because DOE stored topsoil and material from the mountain during site characterization, it would need no additional land to provide soil for reclaiming the material taken from the mountain or for backfilling holding ponds or the reclamation of other previously disturbed areas. Therefore, the No-Action Alternative would not require the disturbance of additional land at the site. The disturbed land would be restored to its approximate preconstruction condition about 100 years earlier than would occur under the Proposed Action.

7.1.2 AIR QUALITY

Transient effects on air quality would result from the exhausts of the heavy equipment that DOE would use during the decommissioning and reclamation activities that the Department expects to complete over a 1-year period. Recontouring and revegetation activities would generate dust containing particulate matter less than 10 micrometers in diameter (PM_{10}). Impacts on air quality would be about the same as those associated with the construction phase during the Proposed Action for the flexible design, as discussed in Chapter 4, Section 4.1.2, because less land would be disturbed by fewer vehicles during decommissioning and reclamation activities. Because the air quality impacts described in Section 4.1.2 represent a small fraction of the regulatory limit (that is, less than 10 percent of regulatory limits), the No-Action Alternative would not adversely affect air quality.

7.1.3 HYDROLOGY

7.1.3.1 Surface Water

The No-Action Alternative would not adversely affect surface water. During decommissioning and reclamation, adherence to such best management practices as stormwater pollution prevention plans would ensure that cleared areas and exposed earth would be seeded, graveled, or paved to control runoff and minimize soil erosion. To prevent contamination from heavy equipment, workers would monitor the equipment for leaks and would contain and clean up inadvertent spills of industrial fluids following established spill prevention and cleanup plans. DOE would dismantle and remove most surface structures, equipment, and building materials (DIRS 102188-YMP 1995, p. 2-8), including such items as fuel storage tanks and facilities where petroleum products or potentially hazardous materials like paints and solvents were stored before removal. Hazardous materials removed or generated during decommissioning would be taken from the site and reused, recycled, or disposed of in accordance with applicable regulations (DIRS 102188-YMP 1995, p. 2-8). After closure, contaminant sources would be gone so there could be no movement of contaminants to surface water. The analysis assumed that reclamation activities would be complete about 1 year after the decision to implement the No-Action Alternative, which DOE anticipates would occur in 2002.

As part of the reclamation activities, DOE would recontour the landscape to match its precharacterization conditions, ensuring natural drainage patterns. Because the North and South Portal ramps of the Exploratory Studies Facility slope upward to prevent ingress of surface water, they would not appreciably affect natural drainage patterns. Seeding and other erosion control measures would ensure normal infiltration rates. Under the No-Action Alternative, DOE anticipates that the restoration of natural drainage patterns would be complete about 100 years earlier than under the Proposed Action.

7.1.3.2 Groundwater

The No-Action Alternative would not adversely affect groundwater. DOE would remove all sources of contaminants (such as petroleum products and potentially hazardous materials like paints and solvents) from the site. The entrance ramps of the open portals of the Exploratory Studies Facility are sloped such that surface water would drain away from the openings. During reclamation activities (which would take about 1 year), the Exploratory Studies Facility portals would be closed.

7.1.4 BIOLOGICAL RESOURCES AND SOILS

Approximately 1.4 square kilometers (350 acres) of habitat has been disturbed; most of the disturbance is associated with the Exploratory Studies Facility, the storage area for the material removed from the tunnel, the topsoil storage area, borrow pits, boreholes, trenches, and roads. Site reclamation activities would include removal of structures and equipment, soil stabilization, and revegetation plantings at many of the disturbed sites (DIRS 102188-YMP 1995, all). Proper soil stabilization would prevent erosion. Once the area was reclaimed, stabilized, and planted with natural vegetation, and once activities at the site decreased, the precharacterization floral and faunal diversity would begin to reestablish itself. Some animal species could take advantage of abandoned tunnels for shelter; for example, the tunnels could provide attractive roosting and nesting sites for bats. Individuals of the threatened desert tortoise species could be adversely affected during the decommissioning and reclamation of the site. The No-Action Alternative would have no other adverse effects on biological resources or soils. In addition, the reclamation would result in the restoration of 1.4 square kilometers of habitat.

7.1.5 CULTURAL RESOURCES

The potential effects of other uses of the Yucca Mountain site on cultural resources are not known because no other uses have been identified; therefore, no assessment of the effects is possible. If the land were to revert to the previous controlling authorities, the stewardship of cultural resources would be consistent with applicable policies, regulations, and procedures.

Because no additional land would be required for decommissioning and reclamation activities, disturbances to cultural resources on undisturbed land in the area would be unlikely. Leaving access roads in place could have an adverse impact on cultural resources if the site boundaries are not secure. Preserving the integrity of important archaeological sites and resources important to Native Americans could be difficult if the public had increased access to the site.

7.1.6 SOCIOECONOMICS

Many of the repository workers would shift to decommissioning and reclamation tasks. An average annual workforce of about 1,800 would complete decommissioning and reclamation tasks at the repository site. After decommissioning and reclamation, the Nevada Test Site would assume the responsibility of preventing inadvertent entry to the North and South Portal areas. A small workforce would protect these areas after reclamation.

After the 1-year decommissioning and reclamation period, the decommissioning and reclamation workforce, along with about 1,400 project-related workers employed away from the repository site, would lose their jobs. The total direct employment reduction, therefore, would be about 3,200 at the completion of decommissioning and reclamation. For every direct job lost, about 0.46 indirect job would also be lost (DIRS 104508-CRWMS M&O 1999, all). *Indirect jobs* are those created as a result of direct employment; examples would include jobs that provide essential services, such as medical and police protection, to the individuals directly employed by the project. Therefore, the overall impact of the No-Action Alternative would be the loss of approximately 4,700 jobs in the region of influence.

As stated in Chapter 3, Section 3.1.7.1, approximately 79 percent of workers at the Yucca Mountain site reside in Clark County, 19 percent reside in Nye County, and less than 1 percent reside in Lincoln County or elsewhere. Thus, ending characterization activities would have the greatest potential impact in Clark County. If the region (Clark, Lincoln, and Nye Counties) continued to add about 2,800 new jobs every month, impacts would be offset by continued economic growth (Chapter 3, Section 3.1.7.2). Therefore, terminating site characterization activities would have a very minor impact on socioeconomic factors.

The cessation of repository activities would result in the loss of payments by the Federal Government in lieu of taxes. Nye County collects most of the monies associated with the repository project. The 1997 Nye County budget totaled approximately $83.8 million (county government and school district). During the same period, Nye County received approximately $5.4 million as payment in lieu of taxes (DIRS 105001-CRWMS M&O 1999, all).

7.1.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY FOR ROUTINE OPERATIONS

Chapter 2, Section 2.2.1, describes the actions DOE would take at Yucca Mountain under the No-Action Alternative. During the decommissioning and reclamation phase, these actions would expose workers and members of the public to the nonradioactive and radioactive contaminants discussed in Chapter 4, Section 4.1.3.1. In addition, these actions would place workers at risk for occupational (industrial safety) incidents such as illnesses, injuries, and fatalities. Appendix F, Section F.2.2.2, describes the statistics used to estimate health and safety impacts from industrial safety incidents. Because the activities that workers would perform under the No-Action Alternative would involve risks similar to those during the construction and closure phases of the Proposed Action, DOE used these statistics to estimate worker health impacts.

Worker exposures to nonradioactive contaminants of concern (diesel engine exhaust and mineral dusts potentially containing respirable erionite and crystalline silica) during decommissioning and reclamation activities would be limited by administrative and engineering means. Exposures would be maintained below occupational levels that could affect worker health adversely, as specified by the Occupational Safety and Health Administration and detailed in the project health and safety plan (DIRS 105032-CRWMS M&O 1999, all). Accordingly, worker exposures to nonradioactive contaminants would not contribute to adverse health impacts.

Tables 7-2 and 7-3 summarize the estimated total impacts from workplace industrial hazards and from radiological exposure, respectively, for reclamation activities. Table 7-4 summarizes impacts to members of the public.

Involved and noninvolved worker group losses under the No-Action Alternative would be about 94 total recordable cases of injury and illness, resulting in about 45 lost workday cases and no fatalities (Table 7-2).

Table 7-2. Estimated industrial safety impacts for surface and subsurface workers during decommissioning and reclamation activities at Yucca Mountain.[a]

Group	Total recordable cases	Lost workday cases	Fatalities
Involved workers	80	38	0
Noninvolved workers	13	7	0
Totals	***94***	***45***	***0***

a. Source: For impact statistics, Appendix F, Tables F-9 and F-10 (1 year of construction, higher-temperature operating mode, uncanistered packaging scenario).

Worker population radiation exposures during the year of decommissioning and reclamation activities would result from exposure to radioactive radon decay products that would emanate from the tunnel's rock matrix and from ambient radiation. Exposures to the subsurface workers could result in a collective dose of about 150 person-rem (Table 7-3). Doses to the maximally exposed involved subsurface worker and noninvolved worker could be as high as about 260 millirem and 70 millirem, respectively.

Table 7-3. Estimated radiation doses and health effects for surface and subsurface workers from decommissioning and reclamation activities at Yucca Mountain.[a,b]

Group	Maximally exposed individual (millirem)	LCF[c] risk to the maximally exposed individual	Collective worker dose[d] (person-rem)	LCF[e]
Involved workers	260	0.00010	140	0.055
Noninvolved workers	70	0.00027	7.4	0.0030
Totals	***NA***[f]	***NA***	***150***	***0.057***

a. Source: Appendix F, Table F-11; data adjusted for 1 year of construction activity.
b. The impacts listed would be the result of 1 year of decommissioning and reclamation activities; adapted from construction phase impacts. Worker doses would result from exposure to radon and other terrestrial radiation sources.
c. LCF = latent cancer fatality.
d. The calculation of doses and health effects assumes no worker rotation for exposure control purposes.
e. Expected number of cancer fatalities for populations. Based on a risk of 0.0004 latent cancer per rem for workers (DIRS 101857-NCRP 1993, p. 112).
f. NA = not applicable.

Public radiation exposures during decommissioning and reclamation would result from radon emissions from the subsurface facilities. These exposures could result in an annual dose to the hypothetical maximally exposed individual, about 18 kilometers (11 miles) south of the repository, of 0.43 millirem. The maximum collective dose to the projected population of 76,000 within 80 kilometers (50 miles) would be about 1.7 person-rem (Table 7-4).

Table 7-4. Estimated public radiation doses and health effects from decommissioning and reclamation activities at Yucca Mountain.[a]

Group	Maximally exposed individual (millirem per year)	Annual increase in risk for contracting an LCF[b]	Collective public dose[c] (person-rem)	LCF
Public	0.43	0.00000022	1.7	0.00085

a. The impacts listed would be the result of 1 year of decommissioning and reclamation activities (Table 4-2, higher-temperature operating mode, which was assumed to equate to 1 year of initial construction activities).
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0005 latent cancer per rem for members of the public (DIRS 101857-NCRP 1993, p. 112), and a life expectancy of 70 years for a member of the public.
c. The collective dose to 76,000 individuals living within 80 kilometers (50 miles) would be from radon emissions from the subsurface facilities.

The increased likelihood of the maximally exposed individual worker experiencing a latent cancer fatality would be very small.

7.1.8 ACCIDENTS

Under the No-Action Alternative, DOE would not ship spent nuclear fuel and high-level radioactive waste to Yucca Mountain, and there would be only limited quantities of nonradioactive hazardous or toxic substances. Therefore, accident impacts would be limited to those from traffic and industrial hazards.

Table 7-2 lists impacts from industrial accident scenarios and Section 7.1.14 discusses impacts from traffic accident scenarios.

7.1.9 NOISE

Noise levels during decommissioning and reclamation activities would be no greater than those of site characterization activities. After the decommissioning and reclamation activities were complete, ambient noise would return to levels consistent with a desert environment where natural phenomena account for most background noise (see Chapter 3, Section 3.1.9.1). The No-Action Alternative would not adversely affect the noise levels of the Yucca Mountain region.

7.1.10 AESTHETICS

Site decommissioning and reclamation activities would improve the scenic value of the site. Borrow pits and holding ponds would be filled or graded, stabilized, and revegetated. Most structures would be removed down to their foundations. The North and South Portals would be gated. The surface area of these disturbed areas would represent a small fraction of the total surface area of the repository site and, therefore, would be unlikely to cause adverse impacts to the overall scenic value of the area. Under the No-Action Alternative, the site would be returned to a state as close as possible to the predisturbed state; therefore, DOE would not expect adverse impacts to the scenic value of the area. Site restoration would occur about 100 years earlier than under the Proposed Action.

7.1.11 UTILITIES, ENERGY, AND MATERIALS

Decommissioning and reclamation activities would consume electricity, diesel fuel, and gasoline. Much equipment and many materials would be salvaged and recycled. DOE would recycle buildings as practicable. After the site closed, minimal surveillance activities would require some electricity and gasoline. The No-Action Alternative would not adversely affect the utility, energy, or material resources of the region.

7.1.12 WASTE MANAGEMENT

The decommissioning and reclamation of the Yucca Mountain site would generate some waste requiring disposal, including sanitary sewage, sanitary and industrial solid waste, small amounts of demolition debris, and very small amounts of hazardous waste. DOE would dispose of the wastes as it has during the site characterization activities.

DOE would minimize waste generation by salvaging most of the equipment and many materials and redistributing them to other DOE sites or selling them at public auction. Remaining chemical supplies would be redistributed through the DOE excess program, which collects equipment and materials no longer in use for reassignment to other DOE sites or Federal facilities, donation to state governments, or sale to the public. DOE would preserve, rather than demolish, certain facilities that could be useful in the future, such as the electrical distribution and water supply systems. Sanitary sewage would be disposed of in the onsite septic system. At the end of reclamation activities, DOE would cap the inlets to the septic system and leave the system in place. DOE would dispose of sanitary and industrial solid waste and demolition debris in existing Nevada Test Site landfills, where disposal capacity would be available for about 70 years (DIRS 101803-DOE 1995, p. 8).

7.1.13 ENVIRONMENTAL JUSTICE

An examination of analyses from other technical disciplines associated with terminating characterization and construction activities at Yucca Mountain and decommissioning and reclaiming the site shows no potential for large impacts in areas other than cultural resources and socioeconomics. The cultural resources analysis identified the possibility that increased public access (if roads were left open and site boundaries were not secure) could threaten the integrity of archaeological sites and resources important to Native Americans. The socioeconomic analysis identified a potential loss of as many as 4,700 jobs (see Section 7.1.6).

Disproportionate impacts to minority or low-income populations from potential job losses would not be expected because there is no reason to believe that minority or low-income employees would be any more likely to be affected by job loss.

7.1.14 TRAFFIC AND TRANSPORTATION

Fatalities from project-related traffic would be unlikely during decommissioning and reclamation. As a gauge of the probability of 1 fatality, decommissioning and reclamation activities would require about 1 year to complete, or about one-fifth of the time to construct the repository. The analysis in Appendix J estimated less than 0.7 fatality from traffic accidents during repository construction, so less than 0.15 traffic fatality would be likely during decommissioning and reclamation (see Appendix J, Tables J-64 and J-65, for details).

7.1.15 SABOTAGE

There would be no nuclear materials at the Yucca Mountain site, so sabotage concerns would not be pertinent.

7.2 Commercial and DOE Sites

This section analyzes short- and long-term impacts of continued storage of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites for 10,000 years (the period considered for the Proposed Action). The analysis includes No-Action Scenarios 1 and 2.

The following paragraphs discuss short-term impacts under No-Action Scenario 1. Because the analysis assumed that all sites would maintain institutional control for the first approximately 100 years, the short-term impacts for Scenarios 1 and 2 would be the same. For consistency with the Proposed Action, this analysis assumed the No-Action scenarios would begin in 2002. This analysis considered the Idaho National Engineering and Environmental Laboratory to be a site for naval spent nuclear fuel because the Laboratory stores such fuel.

Under the No-Action Alternative, commercial utilities would manage their spent nuclear fuel at 72 facilities. DOE would manage its spent nuclear fuel and high-level radioactive waste at five facilities (the Hanford Site, the Idaho National Engineering and Environmental Laboratory, Fort St. Vrain (spent nuclear fuel only) the West Valley Demonstration Project (high-level radioactive waste only), and the Savannah River Site). The No-Action analysis evaluated the DOE spent nuclear fuel and high-level radioactive waste at existing sites or at sites where existing Records of Decisions have placed or will of in the onsite septic system. At the end of reclamation activities, DOE would cap the inlets to the septic system and leave the system in place. DOE would dispose of sanitary and industrial solid waste and demolition debris in existing Nevada Test Site landfills, where disposal capacity would be available for about 70 years (DIRS 101803-DOE 1995, p. 8).

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The No-Action Alternative assumes that the spent nuclear fuel and high-level radioactive waste would be treated, packaged, and stored in a condition ready for shipment to a repository. The amount (inventory) of spent nuclear fuel and high-level radioactive waste considered in this analysis would be the same as that for the Proposed Action—70,000 metric tons consisting of 63,000 MTHM of commercial spent nuclear fuel, 2,333 MTHM of DOE spent nuclear fuel, 8,315 canisters of solidified high-level radioactive waste. The 70,000 MTHM would include surplus plutonium in the form of mixed-oxide fuel and immobilized plutonium. In addition, DOE recognizes that more than 107,000 MTHM of commercial and DOE spent nuclear fuel and more than 22,000 canisters of high-level radioactive waste could require storage if a disposal site is not available. Section 7.3 describes the assumptions and analytical methods used to estimate impacts for the total projected inventory of spent nuclear fuel and high-level radioactive waste, referred to as Inventory Module 1, and evaluates the potential impacts of the continued storage of the total projected inventory of commercial and DOE spent nuclear fuel and high-level radioactive waste.

Storage Packages and Facilities at Commercial and DOE Sites

A number of designs for storage packages and facilities at the commercial and DOE sites would provide adequate protection from the environment for packages containing spent nuclear fuel and high-level radioactive waste. Because it has not selected specific designs for most locations, DOE selected a representative range of commercial and DOE designs for analysis, as described in the following paragraphs. In addition, for purposes of analysis, the No-Action Alternative assumed that the commercial and DOE sites have sufficient land to construct the initial and replacement storage facilities and that the initial construction of all dry storage facilities would be complete and the facilities filled by 2002.

Spent Nuclear Fuel Storage Facilities

Most commercial sites currently store their spent nuclear fuel in water-filled basins (fuel pools) at the reactor sites. Because they have inadequate storage space, some commercial sites have built what are called *independent spent fuel storage installations*, in which they store dry spent nuclear fuel above ground in metal casks or in welded canisters inside reinforced concrete storage modules. Other commercial sites plan to build independent spent fuel storage installations so they can proceed with the decommissioning of their nuclear plants and termination of their operating licenses (for example, the Rancho Seco and Trojan plants). Because commercial sites could elect to continue operations until their fuel pools became full and then cease operations, the EIS analysis initially considered ongoing wet storage in existing fuel pools to be a potentially viable option for spent nuclear fuel storage. However, dry storage is almost certainly the preferred option for long-term spent fuel storage at commercial sites for the following reasons (DIRS 101899-NRC 1996, pp. 6-76 and 6-85):

- Dry storage is a safe economical method of storage.
- Fuel rods in dry storage are likely to be environmentally secure for long periods.
- Dry storage generates minimal, if any, low-level radioactive waste.
- Dry storage units are simpler and easier to maintain.

Accordingly, this EIS assumes that all commercial spent nuclear fuel would be stored in dry configurations in independent spent fuel storage installations at existing locations (Figure 7-2 is a photograph of a typical independent spent fuel storage installation). This assumption includes spent nuclear fuel at sites that no longer have operating nuclear reactors. Although most utilities and DOE have not constructed independent spent fuel storage installations or designed dry storage containers, this analysis evaluates the impacts of storing all commercial and some DOE spent nuclear fuel in horizontal concrete storage modules (Figure 7-3) on a concrete pad at the ground surface. Concrete storage modules have openings that allow outside air to circulate and remove the heat of radioactive decay. The analysis assumed that spent nuclear fuel from both pressurized-water and boiling-water reactors would be stored in a dry storage canister inside the concrete storage module. Figure 7-4 shows a typical dry storage canister, which would consist of a stainless-steel outer shell, welded end plugs, pressurized helium internal environment, and criticality-safe geometry for 24 pressurized-water or 52 boiling-water reactor fuel assemblies.

The combination of the dry storage canister and the concrete storage module would provide safe storage of spent nuclear fuel as long as the fuel and storage facilities were maintained properly. The reinforced concrete storage module would provide shielding against the radiation emitted by the spent nuclear fuel. In addition, the concrete storage module would provide protection from damage resulting from accidents such as aircraft crashes and from natural hazard phenomena such as earthquakes or tornadoes.

This analysis assumed that DOE would store dry spent nuclear fuel at the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and Fort St. Vrain in stainless-steel canisters inside above-grade reinforced concrete storage modules. In addition, it assumed that the design of DOE above-ground spent nuclear fuel storage facilities would be similar to the independent spent fuel storage installations at commercial sites.

The analysis assumed that DOE would store spent nuclear fuel at Hanford in a dry cask in below-grade storage facilities. DOE would store Hanford N-Reactor fuel in the Canister Storage Building, which would consist of three below-grade concrete vaults with air plenums for natural convective cooling. The vaults would contain vertical storage tubes made of carbon steel. Each storage tube, which would hold two spent nuclear fuel canisters, would be sealed with a shield plug. DOE would cover the vaults with a structural steel shelter.

High-Level Radioactive Waste Storage Facilities

With one exception, this analysis assumed that DOE would store solidified high-level radioactive waste in dry below-grade, high-level radioactive waste storage facilities (Figure 7-5). At the West Valley Demonstration Project, the analysis assumed that DOE would use a dry storage system similar to a commercial independent spent nuclear fuel storage installation for high-level radioactive waste.

A high-level radioactive waste storage facility consists of four areas: below-grade storage vaults, an operating area above the vaults, air inlet shafts, and air exhaust shafts. The canister cavities are galvanized-steel large-diameter pipe sections arranged in a grid. Canister casings are supported by a concrete base mat. Space between the pipes is filled with overlapping horizontally-stepped steel plates that direct most of the ventilation air through the storage cavities.

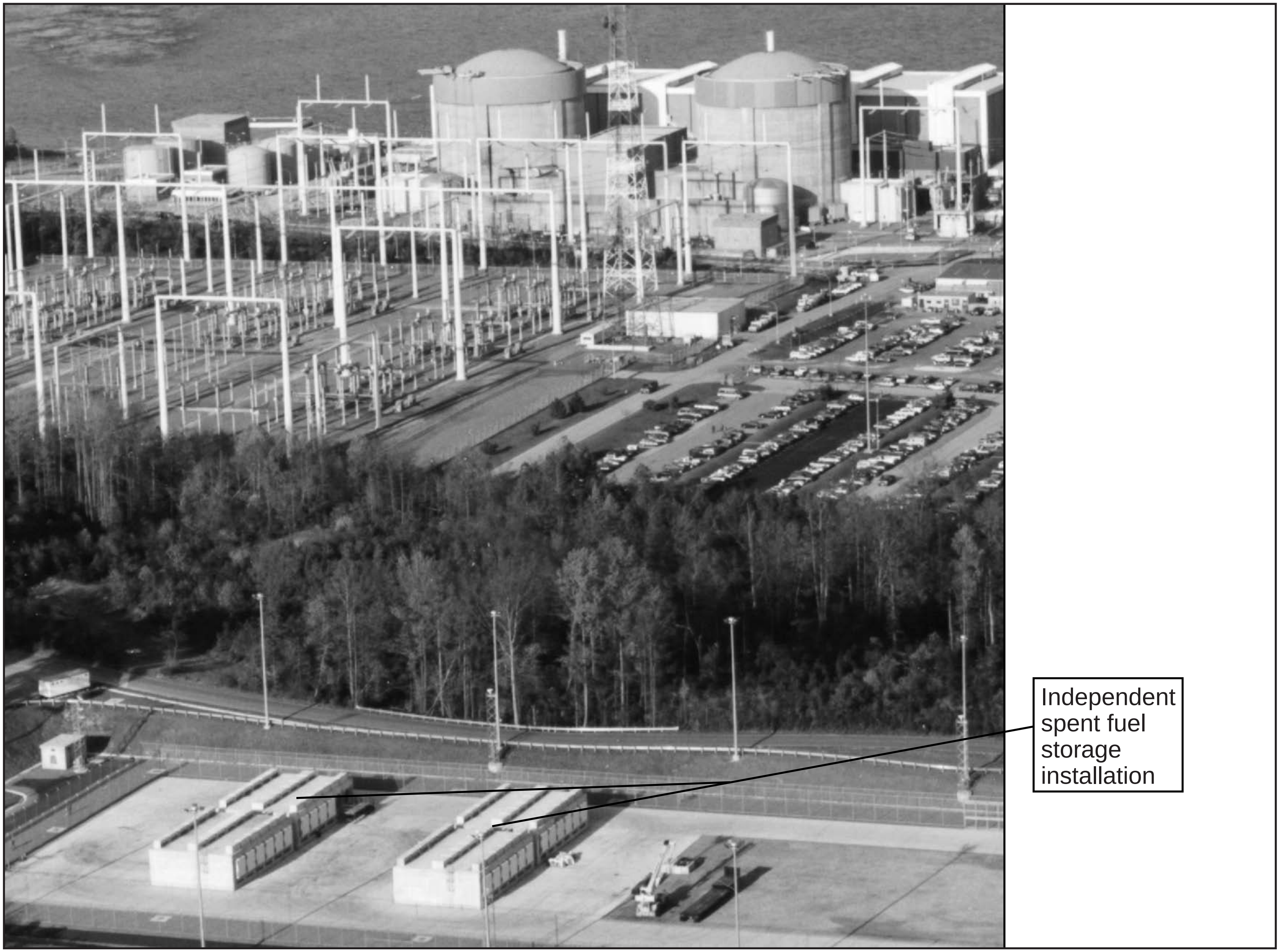


Figure 7-2. Typical independent spent fuel storage installation.

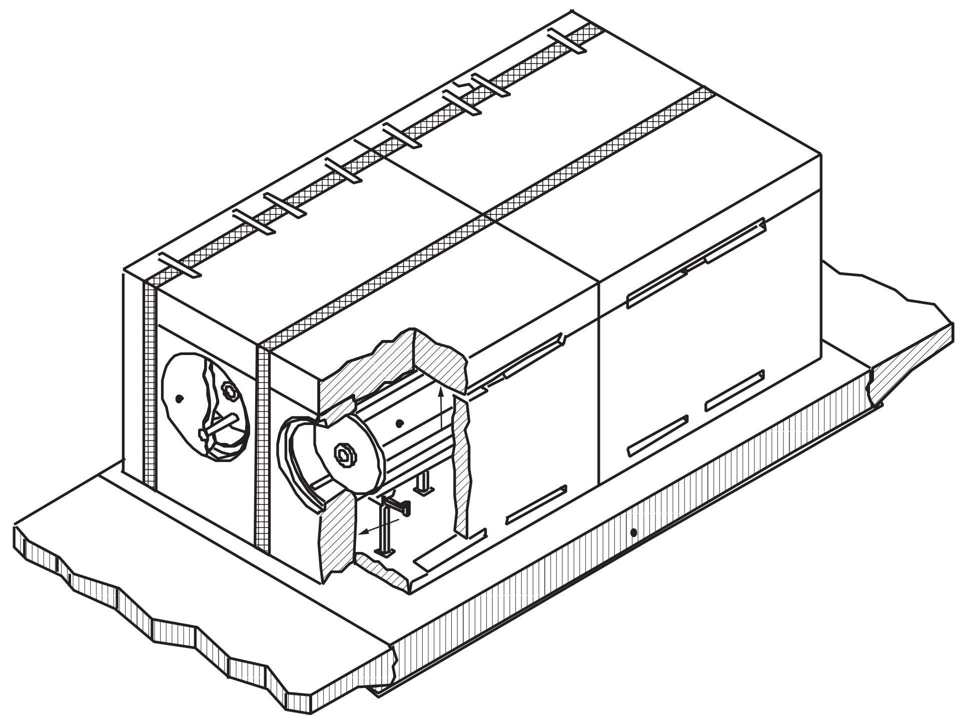


Figure 7-3. Spent nuclear fuel concrete storage module.

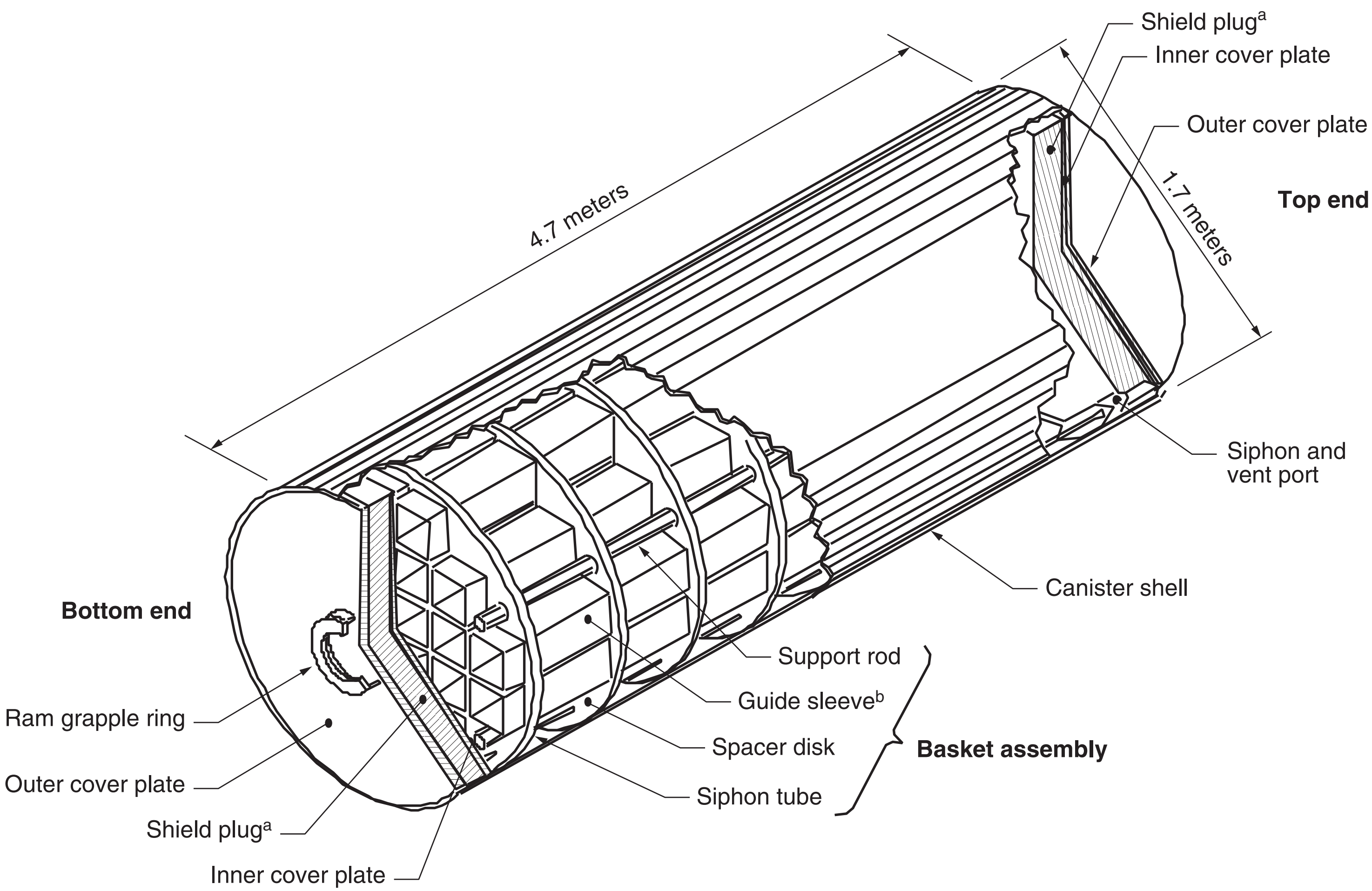
The below-grade storage vault would be below the operating floor, which would be slightly above grade. The storage vault would be designed to withstand earthquakes and tornadoes. In addition, the operating area would be enclosed by a metal building, which would provide weather protection and prevent the infiltration of precipitation. The storage vault would be designed to store the canisters and protect the operating personnel, the public, and the environment for as long as the facilities were maintained. The surrounding earth, concrete walls, and a concrete deck that would form the floor of the operating area would provide radiation shielding. Canister cavities would have individual precast concrete plugs.

Each vault would have an air inlet, air exhaust, and air passage cells. The storage facility's ventilation system would remove the heat of radioactive decay from around the canisters. The exhaust air could pass through high-efficiency particulate air filters before it discharged to the atmosphere through a stack. As an alternative, natural convection cooling without filters could be used. The oversized diameter of the pipe storage cavities would allow air to pass around each cavity.

7.2.1 NO-ACTION SCENARIO 1

Under Scenario 1, 72 commercial sites and 5 DOE sites would store spent nuclear fuel and high-level radioactive waste for 10,000 years. Institutional control, which would be maintained for the entire 10,000-year period, would ensure regular maintenance and continuous monitoring at these facilities that would safeguard the health and safety of facility employees, surrounding communities, and the environment. The spent nuclear fuel and immobilized high-level radioactive waste would be *inert* material encased in durable, robust packaging and stored in above- or below-grade concrete facilities. Release of contaminants to the ground, air, or water would not be expected during routine operations.

DOE and commercial utility workers would perform all maintenance including routine industrial maintenance and maintenance unique to a nuclear materials storage facility under standard operating



All materials 304 stainless steel except as noted.

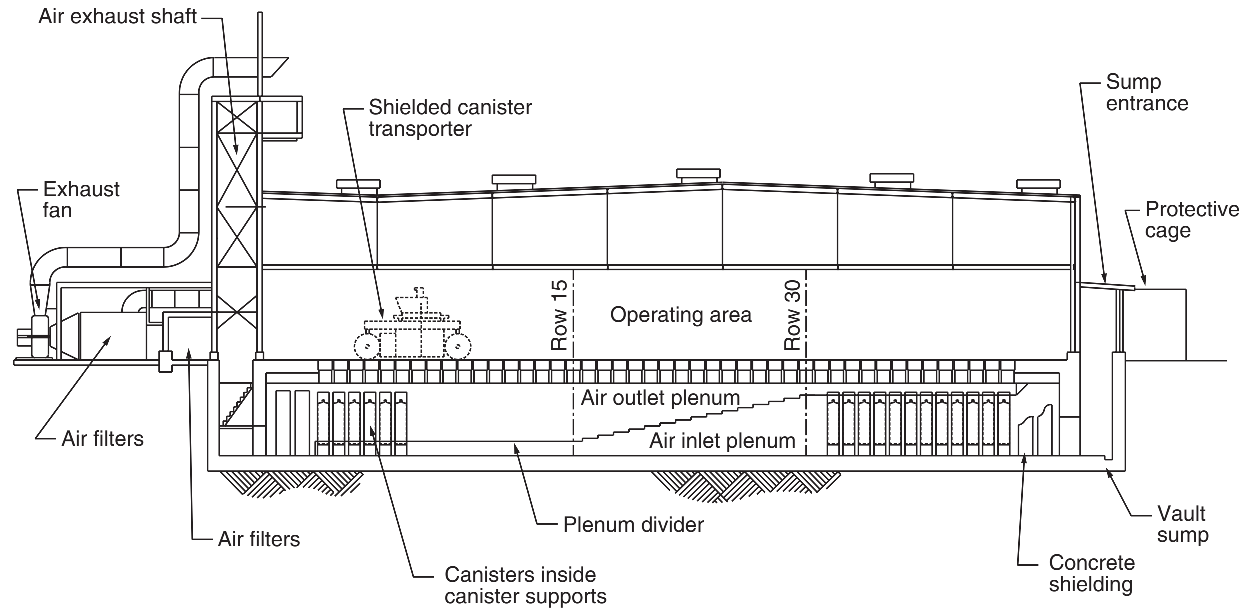
a. Shield plug would be lead.

b. Borated neutron absorber plate for boiling-water reactor spent nuclear fuel assemblies.

To convert meters to feet, multiply by 3.2808.

Source: Modified from DIRS 101910-Poe (1998, p. 1-5).

Figure 7-4. Spent nuclear fuel dry storage canister.



Source: Derived from DIRS 101910-Poe (1998, pp. 4-7, 4-8, and 4-11).

Figure 7-5. Conceptual design for solidified high-level radioactive waste storage facility.

procedures and best management practices to ensure minimal releases of contaminants (industrial and nuclear) to the environment and minimal exposures to workers and the public. This analysis assumed that DOE would manage these facilities in accordance with Departmental rules (10 CFR Part 835) and Orders (see Chapter 11) and that commercial facilities would meet applicable environmental safety and health requirements. It also assumed that storage facilities would require replacement every 100 years and that they would undergo major repairs halfway through the first 100-year cycle. Chapter 2, Section 2.2, provides additional information pertaining to Scenario 1. The following sections treat short- and long-term impacts separately where appropriate.

7.2.1.1 Land Use and Ownership

The storage facilities for spent nuclear fuel and high-level radioactive waste would be at commercial and DOE sites. Facilities would require replacement every 100 years (beginning about 2110), which would occur on land immediately adjacent to the existing facilities. The land required for a storage facility typically would be a few acres, a small percentage of the land available at current sites. An environmental assessment of an independent spent fuel storage installation determined that operation of the facility would require no more land than it occupied (DIRS 101898-NRC 1991, p. 20).

At the end of each 100-year cycle, a new facility constructed next to the old one would contain the spent nuclear fuel or high-level radioactive waste. The old facility would be demolished and the land reclaimed and maintained for the next 100 years. By alternating the facility between two adjacent locations, minimal land would be required.

Storage facilities would be on land owned by either DOE or a utility. Storage at these sites would be unlikely to affect land use and ownership.

7.2.1.2 Air Quality

As a part of routine operations, best management practices and effective monitoring procedures would ensure that any contaminant releases to the air would be minimal and would not exceed current regulatory limits (40 CFR Part 61 for hazardous air pollutant emissions and Part 50 for air quality standards). Therefore, the No-Action Alternative would not produce adverse impacts to air quality during routine operations.

The analysis assumed that the storage facilities would require complete replacement every 100 years. During the construction of the replacement facility, exhaust from construction vehicles would temporarily increase local levels of hydrocarbons, carbon monoxide, and oxides of nitrogen, but these and other atmospheric pollutants would be likely to remain within National Ambient Air Quality Standards (see Chapter 3, Table 3-5). Temporary increases in particulate matter would result from these construction activities. Mitigation measures such as watering unpaved roads would limit the generation of fugitive dust. In addition, after replacement the old site would be seeded, graveled, or paved to reduce air emissions. Detrimental air quality impacts would be short-term, minimal, and transient.

Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements; these impacts were not included in the overall impact estimates. Long-term dry storage canister degradation would be highly variable and difficult to estimate from site to site, and DOE did not want to overestimate the accompanying air quality impacts from repackaging.

7.2.1.3 Hydrology

7.2.1.3.1 *Surface Water*

As part of routine operations, best management practices such as stormwater pollution prevention plans and stormwater holding ponds would ensure that, in the unlikely event of an inadvertent contaminant release, contaminants did not reach surface-water systems. Effective monitoring procedures would ensure that operation of the facility did not adversely affect surface waters and that no discharges would contaminate surface waters in excess of drinking water regulatory limits (40 CFR Part 141). Detention basins would capture all runoff, which would be monitored for contamination and treated, as necessary, before it was released to the environment. If the storage facility required active cooling systems, those systems would be designed to contain any inadvertent spill of operating fluids so they could not reach the environment. Therefore, No-Action Scenario 1 would be unlikely to produce adverse impacts to surface-water quality during routine operations.

During construction of the replacement storage facilities, adherence to stormwater pollution prevention plans would ensure that cleared areas and exposed earth would be seeded, graveled, or paved to control runoff and minimize soil erosion that could adversely affect surface-water quality. Surface-water runoff detention ponds would prevent eroded material from entering surface water systems. These erosion control practices would ensure minimal impacts to surface-water quality during construction. To prevent contamination from construction equipment, workers would monitor the equipment for leaks. Inadvertent spills of industrial fluids would be contained and cleaned up in accordance with established spill prevention and cleanup plans. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to surface-water quality during construction operations.

7.2.1.3.2 *Groundwater*

During routine operations, best management practices such as spill prevention and cleanup plans and procedures and effective monitoring procedures would ensure that inadvertent contaminant releases would not reach groundwater. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to groundwater quality during routine operations.

The spent nuclear fuel storage facilities at the commercial sites would be surface structures with shallow foundations such that their construction would not disturb groundwater systems. Some DOE storage facilities would be subsurface structures for which construction might require minimal dewatering of the groundwater aquifer. However, the area occupied by the structure would be small in relation to the size of the aquifer, so no adverse impacts would be likely to result from dewatering activities.

Excavations would remove the soil buffer between surface activities and groundwater, increasing the likelihood of groundwater contamination from an inadvertent spill or leak of construction-related fluids (for example, diesel fuel, oil, hydraulic fluids). Construction activities would be as described above for surface water; thus, the penetration of spilled construction fluids to groundwater would be unlikely. Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to groundwater quality during construction operations.

7.2.1.4 Biological Resources and Soils

Impacts to biological resources or soils from the construction and operation of spent nuclear fuel and high-level radioactive waste storage facilities would be minimal. Heat from the storage modules would not affect nearby vegetation. The storage facilities would be fenced to keep wildlife out. However, some smaller animal species could take advantage of the warm air from storage facility vents in winter, and individual animals could receive adverse impacts, including death, from direct exposure to radiation. As the heat of radioactive decay decreased, these sites would become less attractive to animals seeking warm environments.

The storage facilities would have a minimal effect on the soil. Because the operating and decommissioned facilities would alternate between two locations, the amount of soil disturbed by construction would be very small. By adhering to best management practices and standard operating procedures, DOE expects that spills would be minimal. A spill would be contained and cleaned up immediately, thus minimizing the area of soil affected.

7.2.1.5 Cultural Resources

Replacement spent nuclear fuel and high-level radioactive waste storage facilities would generally be on undeveloped land in rural areas owned by DOE or the commercial utilities. The size of each facility and supporting infrastructure would be small enough to avoid known cultural resources. If construction activities uncovered previously unknown archaeological sites, human remains, or funerary objects, DOE or the commercial utility would comply with Executive Orders and Federal and state regulations for the protection of cultural resources (see Chapter 11, Section 11.2.5, for details). Therefore, the No-Action Alternative would be unlikely to produce adverse impacts to cultural resources during construction and operations.

7.2.1.6 Socioeconomics

Storage facilities for spent nuclear fuel and high-level radioactive waste would be at existing DOE and commercial sites. A staff of about eight workers (two individuals on duty per shift, 24 hours per day) would monitor and maintain each facility (DIRS 104596-Orthen 1999, Table 2, p. 4). The analysis assumed that facilities would require replacement every 100 years, and that there would be a major facility repair halfway through the first 100-year cycle. Facility replacement every 100 years would require approximately 40 workers for 2 years (DIRS 104596-Orthen 1999, Table 2 and Table 6). Major repairs halfway through the first 100-year cycle would require about 40 workers for 1 year (DIRS 104596-Orthen 1999, Table 2 and Table 6).

Each of the 77 sites that stores spent nuclear fuel or high-level radioactive waste employs monitoring and maintenance personnel. Additional staffing for facility replacement [and the one-time major repair (see DIRS 104596-Orthen 1999, Tables 1 and 2)] would be temporary and comprise about 40 employees at a site during construction. (Construction of DOE facilities could require more workers, but the Department would have only five of these facilities reconstructed every 100 years.) This temporary increase in employment would be small in proportion to the existing workforces in affected communities. Therefore, the No-Action Alternative would be unlikely to have adverse effects on socioeconomic factors such as infrastructure and regional economy.

7.2.1.7 Occupational and Public Health and Safety

7.2.1.7.1 *Nonradiation Exposures*

Maintenance, repairs, repackaging, and construction at the storage facilities would be conducted in accordance with requirements of the Occupational Health and Safety Administration and National Institute of Occupational Safety and Health. Administrative controls and design features would minimize worker exposures to industrial nonradioactive hazardous materials during the construction and operation of the storage facilities so exposures would remain below hazardous levels.

7.2.1.7.2 *Industrial Hazards*

The industrial hazards evaluated were (1) total recordable injury and illness cases, (2) lost workday cases associated with workplace injuries and illnesses, and (3) workplace fatalities. The estimates of these traumas were based primarily on the staffing level of involved workers assigned to spent nuclear fuel and high-level radioactive waste management tasks, coupled with representative workplace loss indicators maintained by the Bureau of Labor Statistics (DIRS 148091-BLS 1998, all) or the DOE Computerized Accident/Incident Reporting System database (DIRS 147938-DOE 1999, all). Involved worker risk exposure estimates were based on crew sizes to determine the number of full-time equivalent work years assigned to construction and to operations, surveillance, and maintenance tasks. DOE used representative historic total recordable case, lost workday case, and fatality incident data to project the associated trauma incidence based on the number of workers and their job functions.

This analysis assumed that replacement facilities would be constructed every 100 years and that a major repair and upgrade of the initial facilities would be required once after the first 50 years. Impacts from decommissioning retired facilities were included as part of construction.

For the approximately 100-year construction and operation cycle (2002 to 2116), about 72,000 full-time equivalent work years of effort would be required to maintain and repair about 6,600 concrete storage modules and 4 below-grade storage vaults at the 72 commercial and 5 DOE sites (DIRS 104596-Orthen 1999, Tables 1, 6, and 7). Based on this level of effort, as listed in Table 7-5, about 2,300 industrial safety incidents would be likely, resulting in about 1,000 lost workday cases and 2 fatalities (an average of 1 fatality every 50 years).

In addition, for the remaining 9,900 years, Table 7-5 indicates about 290,000 estimated industrial safety incidents, of which about 130,000 would be lost workday cases and 320 would involve fatalities (an average of 1 fatality every 30 years or about one every 2,500 years at each of the 77 sites). Surveillance tasks would consume 94 percent of the total worker level of effort, construction tasks would consume nearly all of the remaining 6 percent, and operations tasks would consume less than 0.001 percent (DIRS 104596-Orthen 1999, Table 2).

7.2.1.7.3 *Radiation Exposures*

Table 7-5. Estimated industrial safety impacts at commercial and DOE sites during the first 100 years and the remaining 9,900 years of the 10,000-year analysis period under Scenario 1.[a]

Industrial safety impacts	Short-term[b] (100 years) construction and operation	Long-term (9,900 years)[c] construction and operation
Total recordable cases	2,300	290,000
Lost workday cases	1,000	130,000
Fatalities	2.4	320

a. Source: DIRS 104596-Orthen (1999, Tables 6 and 7).
b. The estimated impacts would result from a single 100-year period of storage module construction (renovation), operation, surveillance, and repair.
c. Period from 100 to 10,000 years.

For Scenario 1, the analysis assumed that the facilities would undergo major repairs once during the first 100 years and would be replaced every 100 years thereafter. Very low exposures to future construction workers would occur as they built replacement facilities adjacent to the existing facilities. Transferring the dry storage canisters from old to new concrete storage modules would result in some additional exposures to workers.

During normal operations, facility workers would be exposed to low levels of external radiation while performing routine surveillance and monitoring activities, changing high-efficiency particulate air filters on ventilation systems (for high-level radioactive waste storage facilities), transferring dry storage canisters between concrete storage modules, and maintaining and repairing the facilities. In addition, individuals employed at the nearby nuclear powerplant but not directly involved with activities at the spent nuclear fuel storage facility (noninvolved workers) would be exposed to low levels of external radiation emanating from the filled concrete storage modules. Activities within the facility boundaries would be in accordance with DOE or Nuclear Regulatory Commission guidelines for nuclear facility worker protection (10 CFR Part 835 and 10 CFR Part 20). Table 7-6 lists estimated maximum annual individual doses and the total average collective dose for worker populations during the 100- and 10,000-year analysis periods for commercial and DOE sites.

The Scenario 1 analysis treated the dose rates from DOE spent nuclear fuel as equivalent to commercial spent nuclear fuel on a volume basis. This simplifying assumption had minimal effect on estimated individual and population doses because of the relatively small quantities of DOE spent nuclear fuel (less than 10 percent of the total) and essentially equal radiation exposure rates in comparison to commercial spent nuclear fuel on a volume basis. The analysis separated the calculation of dose rates from high-level radioactive waste because of the difference in source materials.

For Scenario 1, dose rates from high-level radioactive waste were estimated based on the isotopic distributions provided in Appendix A, Tables A-28, A-29, and A-30. As with commercial and DOE spent nuclear fuel, estimated dose rates to facility workers considered shielding provided by the concrete facility structures and decay over the 10,000-year analysis period. However, because of the relatively large distance from the storage facilities to the site boundary [typically more than 3 kilometers (2 miles) at the Hanford Site, the Idaho National Engineering and Environmental Laboratory, and the Savannah River Site], doses to the public were not included. Although the distance to the site boundary at the West Valley Demonstration Project is less than 3 kilometers, not including public exposures from above-grade storage facilities would result in a very small underestimation of impacts because DOE stores only about 4 percent of the high-level radioactive waste at that facility.

Very small air quality impacts would be likely from repackaging materials removed from dry storage containers that could degrade to the point that they no longer met licensing requirements. However, overall impact estimates did not include these impacts because long-term dry storage canister degradation would be highly variable and difficult to estimate from site to site, and DOE did not want to overestimate the accompanying air quality impacts from repackaging.

Table 7-6. Estimated radiological impacts (dose) and consequences from construction and routine operation of commercial and DOE spent nuclear fuel and high-level radioactive waste storage facilities – Scenario 1.[a]

Receptor	Short-term (100 years) construction and operation	Long-term (9,900 years) construction[b] and operation
Population[c]		
MEI[d] (millirem per year)	0.20	0.06
Dose[e] (person-rem)	810	5,200
LCFs[f]	0.41	2.6
Involved worker[g]		
MEI[h] (millirem per year)	170	50
Dose[e] (person-rem)	2,600	24,000
LCFs[f]	1.0	10
Noninvolved workers[i]		
MEI[j] (millirem per year)	13	0[k]
Dose[e] (person-rem)	36,000	0[k]
LCFs[f]	15	0[k]

a. Source: Adapted from DIRS 101898-NRC (1991, all); DIRS 104596-Orthen (1999, all).
b. Assumes construction of 6,600 concrete storage modules and three below-grade vaults at 77 sites every 100 years (DIRS 104596-Orthen 1999, Table 1).
c. Members of the general public living within 3 kilometers (2 miles) of the facilities; estimated to be 140,000 over the first approximately 100 years and approximately 14 million over the duration of the analysis period [estimated using DIRS 102204-Humphreys, Rollstin, and Ridgely (1997, all)].
d. MEI = maximally exposed individual; assumed to be approximately 1.4 kilometers (0.8 mile) from the center of the storage facility (DIRS 101898-NRC 1991, p. 22).
e. Estimated doses account for radioactive decay.
f. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0004 and 0.0005 latent cancer fatality per rem for workers and members of the public, respectively (DIRS 101857-NCRP 1993, p. 112), and a life expectancy of 70 years for a member of the public and a 50-year career for workers.
g. Involved workers would be those directly associated with construction and operation activities (DIRS 101898-NRC 1991, pp. 23 to 25). For this analysis, the involved worker population would be approximately 1,400 individuals (700 individuals at any one time) at 77 sites over 100 years (DIRS 104596-Orthen 1999, Table 6). This population would grow to about 160,000 over 10,000 years.
h. Based on maximum construction dose rate of 0.11 millirem per hour and 1,500 hours per year (DIRS 101898-NRC 1991, p. 23).
i. Noninvolved workers would be employed at the powerplant but would not be associated with facility construction or operation. For this analysis, the noninvolved worker population would be 80,000 individuals who would receive exposures until the powerplants were decommissioned (50 years).
j. Based on a projected area workforce of 1,200 and an average estimated annual dose of 16 person-rem (DIRS 101898-NRC 1991, p. 24).
k. During this period the powerplants would have ended operation, so there would be no noninvolved workers.

As listed in Table 7-6, the estimated dose to the hypothetical maximally exposed offsite individual during the short-term operational period between 2002 and 2116 would be about 0.20 millirem per year (DIRS 101898-NRC 1991, p. 22). For the remaining 9,900 years of the analysis period (long-term impacts), the dose to the hypothetical maximally exposed individual would decrease to about 0.060 millirem per year because of radioactive decay of the source material. During about the first 100 years, the dose (accounting for radioactive decay) could result over a 70-year lifetime of exposure in an increase of 0.0000043 in the lifetime risk of contracting a fatal cancer, an increase over the lifetime natural fatal cancer incidence rate of 0.0018 percent. During the remaining 9,900 years of the analysis period, the dose could result in an increase of 0.0000013 in the lifetime risk of contracting a fatal cancer, an increase of 0.00055 percent over the lifetime natural fatal cancer incidence rate.

Based on the Nuclear Regulatory Commission computer program SECPOP (DIRS 102204-Humphreys, Rollstin, and Ridgely 1997, all), in 1990 approximately 100,000 people lived within 3 kilometers (2 miles) of some type of commercial nuclear facility (DIRS 101917-Rollins 1998, p. 9). Over the 100-year analysis period, the total number of people that would be exposed would be approximately 140,000 because more than one 70-year lifetime would be spanned during the 100-year period. As listed in Table 7-6, between 2002 and 2116 these people would be likely to receive a total collective dose of 810 person-rem.

Long-term doses and latent cancer fatalities for the approximately 9,900-year period between 2116 and 12010 were based on the assumptions described above, with a few notable exceptions. Impacts to noninvolved workers were not calculated because all of the nuclear powerplants would be closed by the beginning of this period. In addition, the total exposed populations of workers and the public would increase by a factor of 100 above the 100-year exposed population because this period would span 140 lifetimes of 70 years. As noted above, for the first 100 years of operation approximately 140,000 people living within 3 kilometers (2 miles) of the storage facilities (100,000 people multiplied by 1.4 consecutive 70-year average human lifetimes [the average number of 70-year lifetimes in 100 years]) would be exposed to external radiation. Over 10,000 years the exposed population would total approximately 14 million people. Therefore, for the period between 2116 and 12010, the offsite population would receive an estimated total collective dose of 5,200 person-rem (adjusted for radioactive decay).

Population statistics indicate that in 1990 cancer caused about 24 percent of the deaths in the United States (DIRS 153066-Murphy 2000, p. 5). If this percentage of deaths from cancer continued, about 24 people out of every 100 in the U.S. population would contract a fatal cancer from some cause. For approximately the first 100 years, the radiation exposure dose from the storage facilities could cause an additional 0.41 latent cancer fatality in the surrounding populations. This would be in addition to about 33,000 cancer fatalities that would be likely in the exposed population of 140,000 from all other causes, or an increase in the natural incidence rate of 0.0012 percent. For the remaining 9,900 years of the analysis, the radiation exposure dose from the storage facilities could result in an additional 2.6 latent cancer fatalities in the surrounding populations. This would be in addition to about 3.3 million cancer fatalities that would be likely to occur in the exposed population of 14 million, or an increase of 0.000079 percent over the natural incidence rate.

The analysis assumed the maximally exposed individual in the involved worker population would be involved in constructing and loading replacement facilities. Assuming a maximum dose rate of 0.11 millirem per hour and an average exposure time of 1,500 hours per year, this construction worker would receive about 170 millirem per year. During about the first 100 years, the dose could result (over 3 years of construction) in an increase in the lifetime risk of contracting a fatal cancer of 0.00020, an increase of 0.090 percent over the national fatal cancer incidence rate of about 24 percent. During the remaining 9,900 years of the analysis period, the dose could result (over 3 years of construction) in an increase in the risk of contracting a fatal cancer of 0.000060, an increase of 0.030 percent over the natural fatal cancer incidence rate.

For the involved worker population of 1,400 individuals, approximately 330 would be likely to contract a fatal cancer from some cause other than occupational exposure. In this population (during the first 100 years), the collective dose of 2,600 person-rem (correcting for decay) between 2002 and 2116 could result in about 1 additional latent cancer fatality (DIRS 104596-Orthen 1999, Table 6), an increase of 0.33 percent over the natural incidence rate of fatal cancers from all causes. During the remaining 9,900 years of the analysis period, the approximately 160,000 involved workers would receive a collective dose of 24,000 person-rem (corrected for decay). This dose could result in an additional 10 latent cancer fatalities (about 1 every 1,000 years during the 9,900-year analysis period), an increase of 0.027 percent over the natural incidence rate of fatal cancers.

Noninvolved workers would be those employed at an operating nuclear powerplant but not directly involved with the day-to-day operation of the spent nuclear fuel storage facility. The analysis assumed that noninvolved workers (about 800 for each of the approximately 100 reactor units at 72 commercial sites) would be generally several hundred to several thousand feet from the storage facilities. In addition, it assumed that noninvolved workers would be at the sites until 2052 (that is, for 50 years).

The Nuclear Regulatory Commission estimated that the dose to noninvolved workers at a nuclear powerplant from a fully loaded independent spent fuel storage installation would be about 16 person-rem per year (DIRS 101898-NRC 1991, p. 24) for the protected-area workforce of 1,200 individuals (DIRS 101898-NRC 1991, p. 26) at the two-unit station of Calvert Cliffs. This collective dose would result in an average maximum dose to the noninvolved worker of 13 millirem per year. Over a 50-year career, this exposure (accounting for radioactive decay) could result in an increase in lifetime risk of contracting a fatal cancer of 0.00018, an increase of 0.077 percent over the natural incidence rate of fatal cancers.

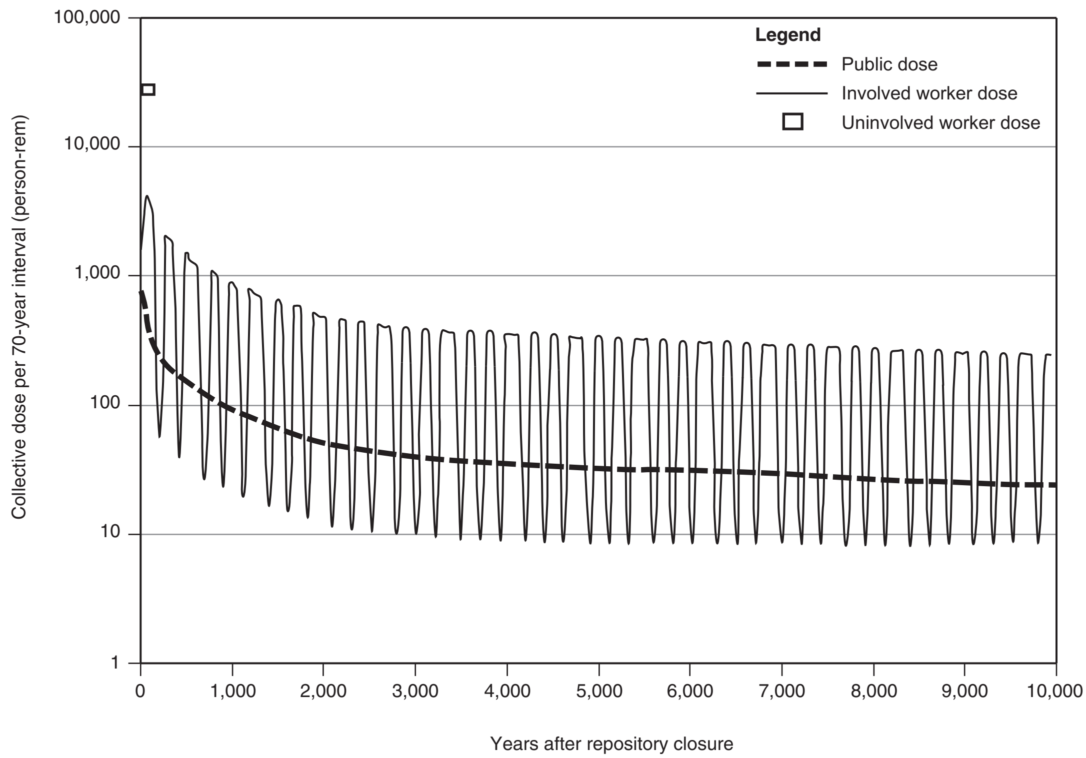
The analysis made the conservative assumption that there are about 80,000 powerplant workers in the United States (800 per reactor unit and about 100 units currently operating), and that these workers would receive radiation exposure from the adjacent storage facilities until powerplant decommissioning, which the analysis assumed will occur in 2052. In the total noninvolved worker population of 80,000 powerplant workers (all sites), the collective dose of 36,000 person-rem (accounting for radioactive decay) between 2002 and 2116 could result in 15 additional latent cancer fatalities. This would be about 0.079 percent more than the 19,000 cancer fatalities that would be likely to occur from all other causes in the same worker population.

Figure 7-6 shows the calculated dose to these populations as a function of time, expressed as 70-year doses. For the noninvolved worker population, the population dose would occur during only the first 70-year interval. The public dose would decrease over time due to the inherent radioactive decay that will occur in the spent nuclear fuel and high-level radioactive waste as time elapses. Many of the radioactive constituents have half-lives substantially less than 10,000 years; therefore, it is likely that the dose to the public would decrease noticeably over time. The involved worker population dose also would decrease over time because of radioactive decay. The involved worker dose would fluctuate as new concrete storage modules were constructed and radioactive material was transferred from the old to the new modules every 100 years. During those 70-year intervals in which construction and transfer would occur, the dose would be higher; the dose would be lower during those 70-year intervals when these activities did not occur.

Because no liquid or airborne effluents would emanate from the storage facilities, direct and air-scattered radiation would comprise the total source of radiation exposure to the public. For populations more than 3 kilometers (2 miles) from the facilities (as is the case for most DOE facilities), direct and air-scattered external radiation exposure would be small (DIRS 101898-NRC 1991, p. 22).

7.2.1.8 Accidents

For Scenario 1, activities at each facility would include surveillance, inspection, maintenance, and equipment replacement, when required. The facilities and the associated systems, which the Nuclear Regulatory Commission would license, would have certain required features. License requirements would include isolation of the stored material from the environment and its protection from severe accident conditions. The Nuclear Regulatory Commission requires an extensive safety analysis that considers the impacts of plausible accident-initiating events such as earthquake, fire, high wind, and tornado. In addition, the license would specify that facility design requirements include features to provide protection from the impacts of severe natural events. These requirements and analyses must demonstrate that the facilities could withstand the most severe wind loading (tornado winds and tornado-generated missiles) and flooding from the Probable Maximum Hurricane with minimal release of radioactive material. This analysis assumed indefinite maintenance of these features for the storage facilities.



Source: Adapted from DIRS 101917-Rollins (1998, all).

Figure 7-6. Collective dose for 70-year intervals for No-Action Scenario 1.

DOE performed an analysis to identify the kinds of events that could lead to releases of radioactive material to the environment prior to degradation of concrete storage modules and found none. The two events determined to be the most challenging to the integrity of the concrete storage modules would be the crash of an aircraft into the storage facility and a severe seismic event.

- DIRS 103711-Davis, Strenge, and Mishima (1998, all) evaluated the postulated aircraft crash and subsequent fire at a storage facility. The analysis showed that falling aircraft components produced by such an event would not penetrate the storage facility and that a subsequent fire would not result in a facility failure. This conclusion is consistent with representative analyses performed in support of Nuclear Regulatory Commission license applications for above-grade dry storage (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all).

  DIRS 103711-Davis, Strenge, and Mishima (1998, all) evaluated aircraft crashes with a velocity of 550 kilometers per hour (340 miles per hour) based on the DOE aircraft crash standard (DIRS 101810-DOE 1996, p. C-7). In a scenario where aircraft velocities could be higher, there would be an increased potential that the intact storage facility could be subject to failure, resulting in a release of radiological materials. DOE has not performed a more detailed analysis of these licensed facilities because the Nuclear Regulatory Commission has a comprehensive program underway to evaluate such events at their licensed facilities, including commercial spent fuel storage facilities. The Commission would be expected to take whatever action is necessary to provide adequate protection to the public from such events.

- For the seismic event, major damage would be unlikely because storage facilities would be designed to withstand severe earthquakes. Even if such an event caused damage, immediate release of radioactive particulates would be unlikely because analyses have identified no mechanism that would cause fuel pellet damage sufficient to create respirable airborne particles (DIRS 103449-PGE 1996, all; DIRS 103177-CP&L 1989, all). Therefore, the source term would be limited to gaseous fission products, carbon-14, and a very small amount of preexisting fuel-pellet dust. Subsequent repairs to damaged facilities or concrete storage modules would preclude the long-term release of radionuclides.

Criticality events are not plausible for Scenario 1 because water, which is required for criticality, could not enter the dry storage canister. The water would have to penetrate several independent barriers, all of which would be maintained and replaced as necessary under Scenario 1. Therefore, DOE determined that potential accident consequences would be bounded by a severe seismic event (see Appendix K, Section K.2.5). DOE analyzed this event and concluded that such an accident scenario would not result in radiological impacts to members of the public in the immediate vicinity of the storage facility. In addition, there would be limited quantities of nonradioactive hazardous or toxic substances stored at the facilities. Therefore, nonradiological accident impacts would be limited to those from industrial hazards and traffic, as discussed in Sections 7.2.1.7.2 and 7.2.1.14, respectively.

7.2.1.9 Noise

During routine operations, noise levels would not affect workers, the public near the facility, or the environment. Most of the storage facilities would have passive cooling, although a few could have active cooling with fans and blowers. Because the storage facilities would be away from population centers or homes, the noise of blowers, if used, would not affect the nearby public. The noise would not be loud enough to produce adverse impacts on the facility workers' hearing.

The analysis assumed for Scenario 1 that the storage facilities would require complete replacement every 100 years. During construction, noise levels due to construction traffic and activities would exceed ambient noise levels. To protect personnel, Occupational Safety and Health Administration standards would be followed (29 CFR 1910.95). The noise could cause wildlife to leave the immediate vicinity of the construction activities, but would not be loud enough to affect individual animals permanently. Adverse impacts to wildlife would be temporary.

7.2.1.10 Aesthetics

Impacts from the storage facilities to aesthetic or scenic resources would be low. There would be two adjacent locations at each site on land that would already be disturbed. Every 100 years, a new facility would be constructed on the idle site, and the storage containers transferred. The old facility would be demolished and the site would remain idle for the next 100 years. Adverse impacts could occur during construction and demolition activities, but these impacts would be short-term and temporary.

7.2.1.11 Utilities, Energy, and Materials

As mentioned above, spent nuclear fuel and high-level radioactive waste storage facilities would have passive cooling, although a few could have active cooling with fans and blowers. Electricity would be required for these cooling systems and to light the storage facilities, but DOE anticipates that the amount of electricity would be small in comparison to the amount available. Fuel and materials would be needed to maintain and repair the facilities and to construct and demolish facilities every 100 years, but DOE expects impacts to these resources to represent a small fraction of the resources available to each of the 77 sites. Therefore, the No-Action Alternative would not produce adverse impacts on these resources during operation and construction activities.

7.2.1.12 Waste Management

Construction of new facilities and demolition of old facilities every 100 years (and the one-time refurbishment of existing facilities after the first 50 years) would generate construction debris and sanitary and industrial solid waste. In addition, routine repairs and maintenance to the facilities and storage containers, routine radiological surveys, and overpacking of failed containers would generate sanitary and industrial solid and low-level radioactive wastes. Because there would not be a dedicated workforce at the storage facilities, only small amounts of sanitary wastes would be generated except during construction periods. The greatest amount of waste would be generated by the demolition of facilities at the 72 commercial and 5 DOE storage sites every 100 years. The demolition of facilities once every 100 years at all the sites would generate, on average, an estimated 770,000 cubic meters (1 million cubic yards) of nonhazardous demolition debris, recyclable steel, and potentially a small amount of low-level waste if a dry storage canister were to fail while in storage (DIRS 104596-Orthen 1999, Table 7). The debris and wastes would be disposed of at commercial or DOE disposal facilities across the Nation. The impacts to available capacity would be spread nationwide, thus minimizing impacts to any one disposal facility. The capacities of the disposal facilities would accommodate the wastes generated at the storage facilities.

7.2.1.13 Environmental Justice

Potential impacts of continued storage with institutional control would be minimal for all populations living near the storage facilities. Because adverse impacts would be unlikely for any population, effects on minority or low-income populations would be unlikely to be disproportionately high and adverse.

Storage facilities would require small areas and would be on lands already owned by commercial utilities or DOE. Therefore, continued storage at these sites would be unlikely to introduce environmental justice concerns. If the United States determines that it will use continued storage at existing sites for the long-term disposition of spent nuclear fuel and high-level radioactive waste, site-specific analyses of storage facilities would be required to determine if environmental justice issues could result. The Nuclear Regulatory Commission has established this approach (DIRS 101899-NRC 1996, p. 9-16).

7.2.1.14 Traffic and Transportation

DOE analyzed short-term impacts (traffic fatalities) that could result from commuting to and from storage facilities for a single 100-year cycle. The amount of travel was determined from estimates of personnel needed to construct the storage facilities, load and reload the canisters into the storage modules, and conduct routine surveillance and repairs (DIRS 104596-Orthen 1999, all). Because the workforce at each storage facility would be small, opportunities for carpooling would be limited. Therefore, the analysis assumed each worker would commute individually.

An estimated 700 workers (see Section 7.2.1.7.3) would commute to and from work approximately 18 million times during the first 100 years. The analysis assumed an average one-way commute of 19 kilometers (12 miles) based on personal travel reported in the Nationwide Personal Transportation Survey by the Oak Ridge National Laboratory (DIRS 102064-FHWA 1999, p. 9). The analysis also used national data to estimate fatalities [in 1994, 1 fatality per 100 million kilometers (about 62 million miles) traveled by automobile (DIRS 148081-BTS 1999, p. 4)] over a single 100-year period. Based on the expected workforce, estimated number of trips, estimated average distance, and fatality data, approximately 7 traffic fatalities would occur in the workforce at the 77 sites in 100 years (or an average of less than 1 fatality every 10 years) (DIRS 104596-Orthen 1999, Table 6).

In addition, the analysis estimated the long-term traffic fatalities for the remaining 9,900-year analysis period. Using the estimated number of full-time equivalent work years of 7.4 million, about 730 traffic fatalities would be likely during the 9,900-year analysis period at the 77 sites (or, on average, less than 1 fatality every 10 years).

The analysis also estimated traffic fatalities and latent cancer fatalities from trucks transporting construction materials to and demolition debris from the 77 sites assuming an 80-kilometer (50-mile) roundtrip distance. For the 9,900-year period, during the construction of replacement facilities, construction vehicles would travel about 1.2 billion kilometers (750 million miles), resulting in approximately 17 prompt traffic fatalities, or less than 1 fatality every 600 years (DIRS 103455-Saricks and Tompkins 1999, Table 4, pp. 34 and 35) and about 0.1 latent fatality from vehicle exhaust emissions.

7.2.1.15 Sabotage

Above-ground storage of spent nuclear fuel and high-level radioactive waste for 10,000 years would entail a continued risk of intruder access at each of the 77 sites. Sabotage could result in a release of radionuclides to the environment around the facility. Under Scenario 1, the analysis assumed that safeguards and security measures currently in place would remain in effect during the 10,000-year analysis period, thereby reducing the risk of sabotage.

As Nuclear Regulatory Commission licensees, the individual sites would be required to comply with Commission regulations and maintain the highest level of security as determined by the Commission, and any results from the reexamination of existing physical security and safeguard systems following the terrorist attack of September 11, 2001.

Because it is not possible to predict whether sabotage events would occur, and if they did, the nature of such events, DOE examined various accident scenarios in this Final EIS, which provide an approximation of the consequences that could occur.

7.2.2 NO-ACTION SCENARIO 2

DOE and commercial utilities intend to maintain control of the nuclear storage facilities as long as necessary to ensure public health and safety. However, Scenario 2 assumes no effective institutional control of the storage facilities after approximately the first 100 years to provide a basis for evaluating an upper limit of potential adverse human health impacts to the public from the continued storage of spent nuclear fuel and high-level radioactive waste. After about 100 years, Scenario 2 assumes that there would be no effective institutional control and that the storage facilities would be abandoned. Therefore, there would be no health risks for workers during that period. For the long-term impacts after about 100 years and for as long as 10,000 years, the analysis assumed that the spent nuclear fuel and high-level radioactive waste storage facilities at 72 commercial and 5 DOE sites would begin to deteriorate and that radioactive materials would be released to the environment, contaminating the local atmosphere, soil, surface water, and groundwater. Appendix K provides details of facility degradation, radioactive material environmental transport, and human radiological exposure and dose models.

Because Scenario 2 assumes effective institutional control during the first 100 years of the 10,000-year analysis period, the short-term impacts of that first 100 years would be the same as the impacts described for Scenario 1 (see Section 7.2.1). Therefore, this discussion focuses on long-term impacts (after the first approximately 100 years). However, after about 100 years under Scenario 2, when there would no longer be effective institutional control, construction and operation activities would not occur at the storage sites; therefore, socioeconomic and cultural resources would be unlikely to receive adverse impacts. In addition, noise would not emanate from the facilities; utilities, energy, or materials would not be expended; waste would not be generated; and workers would not commute to the sites. Thus, after approximately the first 100 years, No-Action Alternative Scenario 2 would not adversely affect socioeconomic and cultural resources; scenic resources; noise; utilities, energy and materials; waste management; or traffic and transportation. Aesthetic resources would not change until the facilities began to degrade, at which time the aesthetic value of the sites would change.

7.2.2.1 Land Use and Ownership

Without maintenance and periodic replacement, facilities, storage containers, and the spent nuclear fuel and high-level radioactive waste would begin to deteriorate. Eventually radioactive materials would contaminate the land surrounding the storage facilities, possibly rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. The amount of land contaminated would depend on several factors including the climate of the region, the amount of spent nuclear fuel and high-level radioactive waste at the site, and the rate of deterioration. Although the size of the affected area would be impossible to predict accurately for each site, DOE believes it would involve tens to hundreds of acres at each of the 77 sites.

By assuming that there would be no effective institutional control, this scenario also assumes that there would not be an orderly conversion of land use and ownership to other uses or ownership and that all knowledge of the purpose and content of the facilities would be lost. This would increase the likelihood that members of the public would move onto storage facility lands because they would not be aware of the potential radioactive material contamination.

7.2.2.2 Air Quality

As discussed in Appendix K, Section K.2.3, the degraded facilities would provide sufficient protection of the spent nuclear fuel and high-level radioactive waste materials to preclude the release of particulate radioactive materials in sufficient quantities to affect air quality adversely. Small releases of gaseous carbon-14 would be likely in the form of carbon dioxide gas but would not adversely affect ambient air quality.

7.2.2.3 Hydrology

7.2.2.3.1 *Surface Water*

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, contaminants would enter surface waters from stormwater runoff from the failed facilities and storage containers and exposed radioactive materials. The introduction of contaminants would continue over a long period until the depletion of the source materials. During this release period, contaminant releases to surface waters could be sufficient to produce adverse impacts to human health. Section 7.2.2.5.3 discusses impacts to the public using this water for drinking.

7.2.2.3.2 *Groundwater*

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, contaminants would enter the groundwater. Once contaminated, aquifers beneath the degraded storage facilities would remain contaminated for the period required for the depletion of the spent nuclear fuel and high-level radioactive waste materials and the migration of the contaminants from the groundwater system. Contaminant concentrations in the groundwater could be sufficient to produce adverse impacts to human health. Section 7.2.2.5.3 discusses impacts to the public using groundwater for drinking, bathing, and irrigation.

7.2.2.4 Biological Resources and Soils

As the concrete storage facilities, storage canisters, and spent nuclear fuel and high-level radioactive waste materials deteriorated, the potential for individual animals to be exposed to radiation at the storage sites would increase. In addition, animals could drink contaminated surface water. Direct radiation from the exposed spent nuclear fuel and high-level radioactive waste storage canisters and concentrations of contaminants in surface waters could produce adverse impacts to animals. While the contaminant exposure could have negative effects, including death, on individual animals, adverse effects to entire populations would be unlikely because the lethal area surrounding the degraded facilities would be limited to a few hundred acres.

Soils at the storage facilities could be contaminated by radioactive materials leaching from the spent nuclear fuel and high-level radioactive waste material. Soils downslope of the facilities could be contaminated by surface-water runoff. Crops grown on these soils would take up some of the contamination, thus making the contaminated soils a pathway for human exposure. Section 7.2.2.5.3 discusses impacts to members of the public from ingesting food grown in or livestock fed from contaminated soils.

7.2.2.5 Occupational and Public Health and Safety

7.2.2.5.1 *Nonradiation Exposures*

Analyses performed for the repository (see Chapter 5, Section 5.6) indicate that concentrations of chemically toxic materials (that is, molybdenum, nickel, vanadium, and chromium) from degraded spent nuclear fuel and high-level radioactive waste packages in the groundwater would be extremely low. Therefore, because of the relatively lower abundance of these materials contained in the stainless steel storage canisters and relatively greater abundance of water and the greater precipitation at the storage locations than at the repository, concentrations of the materials in the groundwater and surface water at the storage sites would likely be much lower than those estimated for the repository. The Department did not attempt to quantify adverse health impacts from chemical toxicity of the waste forms (principally uranium dioxide and *borosilicate glass*) that could occur within the exposed population under Scenario 2. This decision is consistent with the Department's position that care should be taken not to overestimate impacts from the No-Action Alternative.

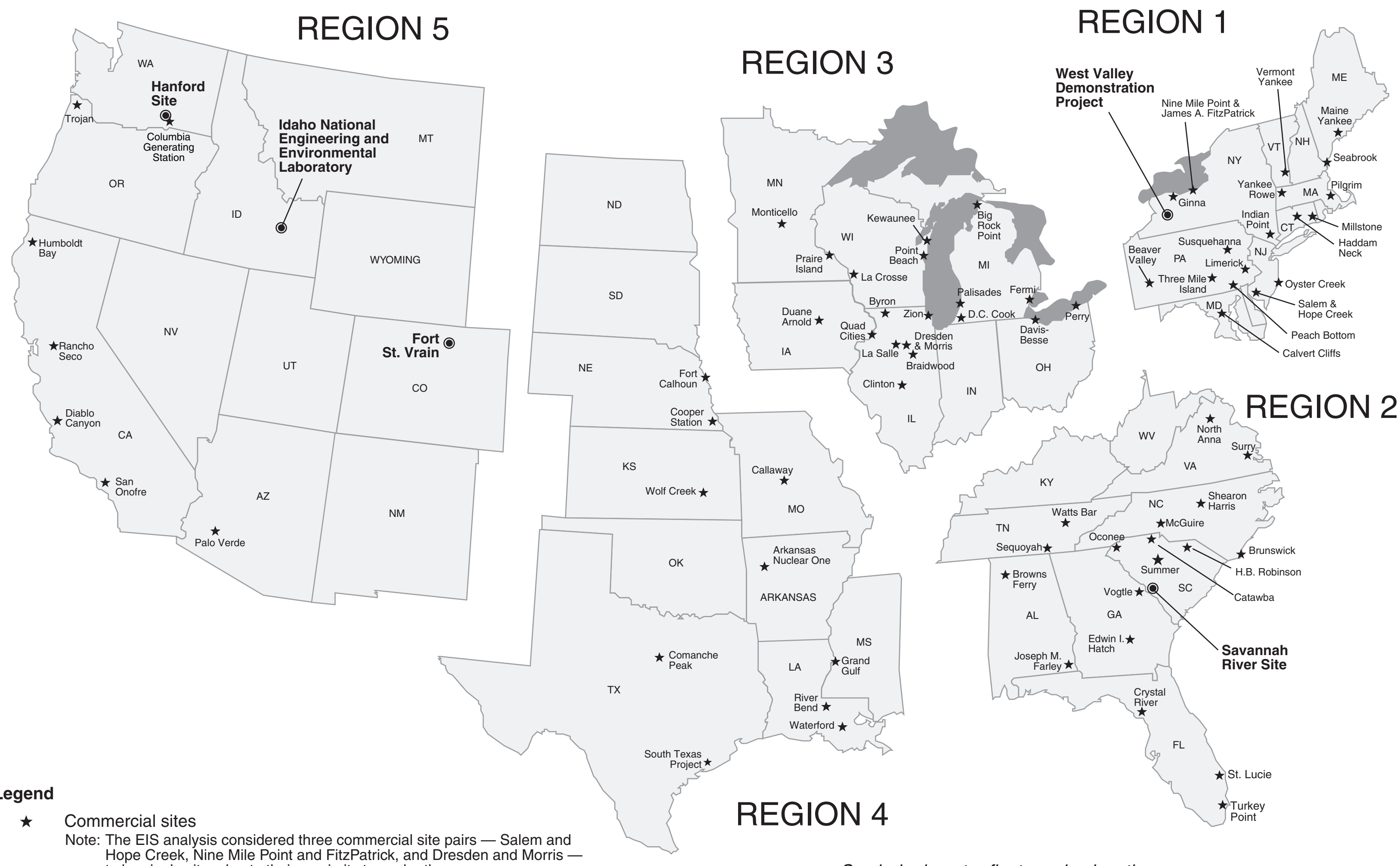
7.2.2.5.2 *Industrial Hazards*

For about the first 100 years, industrial hazards would be the same as for the first 100 years under Scenario 1 (see Section 7.2.1.7.2). After about 100 years, Scenario 2 assumes there would be no effective institutional control and that the storage facilities would be abandoned and, therefore, there would be no industrial safety impacts.

7.2.2.5.3 *Radiation Exposures*

To simplify the analysis, DOE divided the United States into five regions (Figure 7-7). Regional radiological impacts were estimated by assuming all spent nuclear fuel and high-level radioactive waste in a particular region was stored at a single hypothetical site in that region. Appendix K, Section K.2.1.6, provides details of the methods and assumptions used in the regional analysis.

Radiological impacts to occupational workers and the offsite public from initial construction, routine maintenance and operations, and refurbishment after the first 50 years would be the same as those for the same period under Scenario 1 (see Section 7.2.1.7.3 and Table 7-6).



Symbols do not reflect precise locations.

Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Note: None of the facilities evaluated are located in Alaska or Hawaii.

Source: Modified from DIRS 101911-Poe (1998, p. 2).

Figure 7-7. Commercial and DOE sites in each No-Action Alternative analysis region.

For Scenario 2 DOE assumed that after approximately the first 100 years there would be no institutional control and that deterioration of the facilities would occur over time. Based on regional climate and degradation models (see Appendix K), the spent nuclear fuel and high-level radioactive waste storage facilities and dry storage containers would corrode and fail over time, exposing radioactive material to the environment (wind and rain). Once exposed to the environment, the spent nuclear fuel and high-level radioactive waste storage packages and facilities would begin releasing small quantities of radioactive material to the atmosphere (gaseous carbon-14), soil, surface water, and groundwater, resulting in exposures to the public. These released materials could produce chronic exposures to the public, which could result in adverse health impacts. Figure 7-8 shows the conceptual timeline for activities and degradation processes at the storage facilities for Scenario 2.

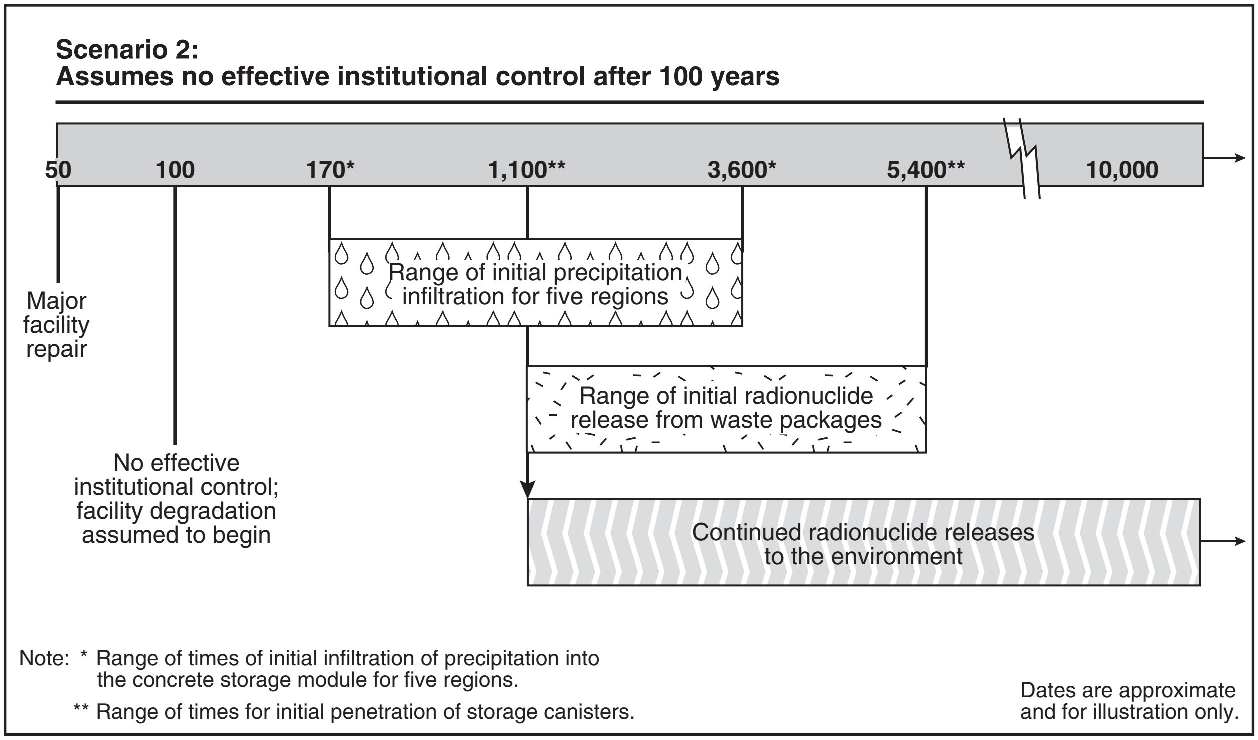


Figure 7-8. Conceptual timeline for activities and degradation processes for No-Action Scenario 2.

Appendix K describes the methods used to estimate impacts to human health from long-term environmental releases and human intrusion. The radiological impacts on human health include internal exposure from intake of radioactive materials in surface water and groundwater.

Table 7-7 lists the estimated radiological drinking water impacts during the 9,900 years under Scenario 2 with the assumption of no effective institutional control. The impacts listed in Table 7-7 are from drinking water only and would result from consuming water from the major waterways contaminated with radioactive materials by groundwater discharge and surface-water runoff from degraded spent nuclear fuel and high-level radioactive waste storage facilities. DOE evaluated

Table 7-7. Estimated long-term collective drinking water radiological impacts to the public from long-term storage of spent nuclear fuel and high-level radioactive waste at commercial and DOE sites – Scenario 2.

9,900-year population dose[a] (person-rem)	9,900-year LCFs[b]	Years to peak impact[c]
6,600,000	3,300	3,400

a. Estimated total population (collective) dose from drinking water pathway (DIRS 101935-Toblin 1999, p. 4).
b. LCFs = latent cancer fatalities; estimated for the exposed population group based on an assumed risk of 0.0005 latent cancer fatality per person-rem of collective dose (DIRS 101857-NCRP 1993, p. 112).
c. Years after period of institutional control when the maximum doses would occur.

other potential impacts to populations (for example, exposure to people living on the contaminated floodplains) and to individuals (for example, consumption of contaminated food) and determined that certain individuals could receive doses as much as three times higher than for drinking water alone but that doses to populations from contaminated floodplains would represent less than 10 percent of the impacts listed in Table 7-7. DOE did not include these impacts in Table 7-7 because the dose to an individual would depend largely on highly variable subsistence habits and because DOE did not want to overestimate the impacts from Scenario 2.

Figure 7-9 shows the locations of the commercial and DOE sites in the United States and the more than 20 major waterways potentially affected. At present, municipal water systems that serve 31 million people have intakes along the potentially affected portions of these waterways. The analysis assumed these populations would remain constant over the entire analysis period (9,900 years). Over the 9,900-year analysis period, about 140 70-year lifetime periods would be affected. Because the analysis estimated that releases would not occur during the first 1,000 years for most regions, the estimated potentially exposed population would be about 3.9 billion.

Table 7-7 indicates that over 9,900 years, a collective drinking water dose of 6.6 million person-rem could result in an additional 3,300 latent cancer fatalities in the total potentially exposed population of 3.9 billion. This latent cancer fatality rate would affect an average of about 24 people per 70-year lifetime, or about 1 latent cancer fatality at each of the 77 sites every 200 years. These radiation-induced latent cancer fatalities would be in addition to about 900 million fatal cancers (using the lifetime fatal cancer risk of 24 percent [DIRS 153066-Murphy 2000, p. 5]) that would be likely from all other causes in the exposed population, an incremental increase over the natural incidence of fatal cancer of about 0.0004 percent.

Figure 7-10 shows the estimated latent cancer fatalities for approximately 140 70-year periods during the 9,900-year period of analysis. The five peaks shown in Figure 7-10 generally result from contributions of each of the five regions (see Appendix K, Figure K-8). The major peak, which would occur about 3,400 years after effective institutional control ended (in 2100), would be due to radionuclide releases at the sites that drain to the Mississippi River and the relatively large populations along the Mississippi and its tributaries.

In addition to the 3,300 potential cancer fatalities under Scenario 2, more than 20 major waterways of the United States that currently supply domestic water to about 31 million people (for example, the Great Lakes; the Mississippi, Ohio, and Columbia Rivers; and many smaller rivers along the Eastern Seaboard) could be contaminated with radioactive material. Under this scenario, the shorelines could be contaminated with long-lived radioactive materials (for example, plutonium, uranium, and americium), resulting in exposures to individuals who came in contact with the sediments and, potentially, an increase in latent cancer fatalities. Because individuals would not be in constant contact with the sediments, these impacts represent a small fraction of the impacts estimated for the drinking water pathways listed in Table 7-7.

For purposes of comparison with impacts associated with the Proposed Action, DOE evaluated potential radiological impacts for a maximally exposed individual by constructing hypothetical exposure scenarios for individuals living near the degraded facilities. The exposure scenarios maximized external and internal exposure over each 70-year lifetime period in the 9,900-year period of analysis. The following paragraphs describe the results of these evaluations.

For Scenario 2, localized impacts to individuals from degraded facilities at the 77 sites could be severe. DOE estimated that within a few hundred years at the several sites where early concrete failure was predicted, hypothetical individuals living close to the storage facilities would receive lethal doses of

Legend

★ Commercial sites

Note: The EIS analysis considered three commercial site pairs — Salem and Hope Creek, Nine Mile Point and FitzPatrick, and Dresden and Morris — to be single sites due to their proximity to each other.

◉ DOE sites

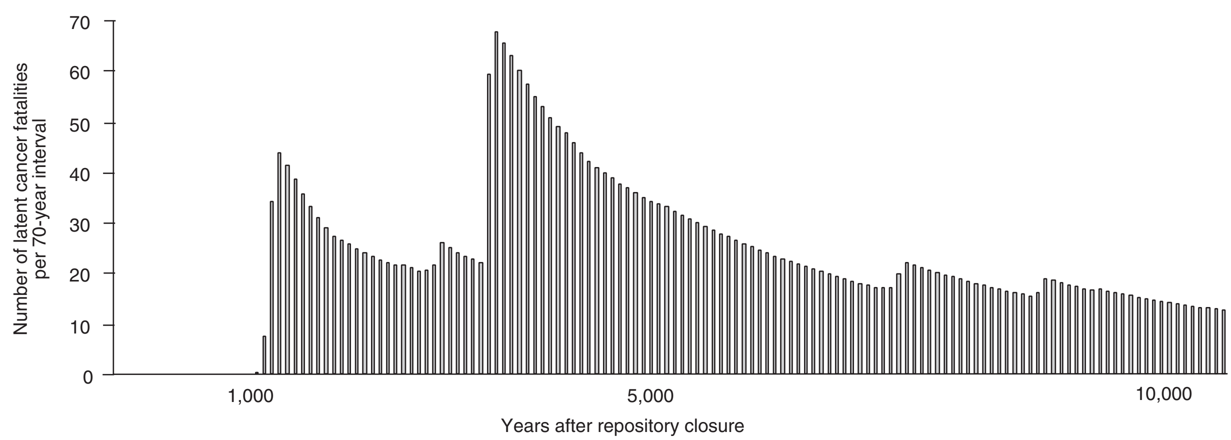
Note: The EIS analysis included the high-level radioactive waste at West Valley. The State of New York owns the high-level radioactive waste and the site. Under the West Valley Demonstration Project Act, DOE is responsible for solidifying and transporting the high-level radioactive waste to a repository.

Symbols do not reflect precise locations.

Note: The Great Lakes and the St. Lawrence Seaway are considered major waterways.

Source: Modified from DIRS 101911-Poe (1998, p. 13).

Figure 7-9. Major waterways near commercial and DOE sites.



Source: Adapted from DIRS 101935-Toblin (1999, p. 8).

Figure 7-10. Potential latent cancer fatalities throughout the United States from No-Action Scenario 2.

external radiation [800 millirem per hour at a distance of 10 meters (33 feet)] from the exposed dry storage containers (see Appendix K, Section K.2.4.2).

To evaluate impacts from ingestion of radioactive materials, the analysis assumed that individuals would live near the degraded storage facilities and would consume contaminated groundwater and food from gardens irrigated with groundwater withdrawn from the contaminated aquifer directly below their locations. DOE estimated that within 6,000 years from now a hypothetical individual living within several hundred meters of a degraded facility could receive an internal committed effective dose equivalent to several thousand rem per year from ingestion of plutonium-239 and -240 (see Appendix F for further information on committed dose equivalent). Using the National Council on Radiation Protection and Measurements risk factors (DIRS 101857-NCRP 1993, p. 112), ingestion of plutonium at this rate could increase the individual's lifetime risk of contracting a fatal cancer after only a few years of exposure.

In addition, DOE estimated impacts for a hypothetical individual living 5 kilometers (3 miles) from the degraded facility on the downgradient of the contaminated aquifer. Although this individual would be too distant from the facility to receive any appreciable external radiation dose, the internal dose from the consumption of contaminated groundwater and contaminated crops could still be as high as 30 rem per year from ingestion of plutonium-239 and -240. Ingestion of plutonium at this rate could increase the individual's risk of contracting a fatal cancer after several decades of exposure. Appendix K provides details on the methods DOE used to evaluate localized impacts.

Uncertainty

This section contains estimates of the radiological impacts of No-Action Scenario 2, which assumes continued above-ground storage of spent nuclear fuel and high-level radioactive waste at sites across the United States. Associated with the impact estimates are uncertainties typical of predictions of the outcome of complex physical and biological phenomena and of the future state of society and societal institutions over long periods. DOE recognized this fact from the start of the analysis; however, the predictions will be valuable in the decisionmaking process because they provide insight based on the best information and scientific judgments available.
This analysis considered five aspects of uncertainty:

- Uncertainties about the nature of changes in society and its institutions and values, in the physical environment, and of technology as technology progresses

- Uncertainties associated with future human activities and lifestyles
- Uncertainties associated with the mathematical representation of the physical processes and with the data in the computer models
- Uncertainties associated with the mathematical representation of the biological processes involving the uptake and metabolism of radionuclides and the data in the computer models
- Uncertainties associated with accident scenario analysis

For the No-Action Scenario 2 analysis DOE has not attempted to quantify the variability of estimated impacts related to possible changes in climate, societal values, technology, or future lifestyles. To simplify the analysis, DOE did not attempt to quantify these uncertainties even though uncertainties with these changes could undoubtedly affect the total consequences reported in Table 7-7 by several orders of magnitude.

DOE attempted to quantify a range of uncertainties associated with mathematical models and input data, and estimated the effect these uncertainties could have on collective human health impacts. By summing the uncertainties (see Appendix K, Sections K.4.1, K.4.2, and K.4.3 for details), DOE estimated that total collective impacts over 10,000 years could have been underestimated by as much as 3 or 4 orders of magnitude. However, because there are large uncertainties in the models used to quantify the relationship between low doses (less than 10 rem) and the accompanying health impacts (see Appendix F, Section F.1.1.5), especially under conditions in which the majority of the population would be exposed at a very low dose rate, DOE believes the actual collective impact could be small.

On the other hand, impacts to individuals (human intruders) who could move to the storage sites and live close to the degraded facilities could be severe. During the early period (200 to 400 years after the assumed loss of institutional control), acute exposures to external radiation from the spent nuclear fuel and high-level radioactive waste material could result in prompt fatalities. In addition, after a few thousand years onsite shallow aquifers could be contaminated to such a degree that consumption of water from those aquifers could result in severe adverse health effects, including premature death. Uncertainties about these localized impacts are related primarily to the inability to predict accurately how many individuals could be affected at each of the 77 sites over the 10,000-year analysis period. In addition, the uncertainties associated with localized impacts would exist for potential consequences resulting from unusual events, both manmade and natural.

Therefore, uncertainties resulting from surface storage where containers are more readily affected by natural phenomena and human behavior (see Appendix K, Table K-14) that cannot be predicted, process model uncertainties, and dose-effect relationships, taken together, could produce the results listed in Table 7-7, overestimating or underestimating the actual impacts by as much as several orders of magnitude.

7.2.2.6 Atmospheric Radiological Consequences

As discussed in Appendix K, Section K.2.3, the analysis assumed that the configuration of the degraded storage facilities would cause debris to cover the radioactive material, which would remain inside the dry storage canisters. While the dry storage canisters could fail sufficiently to permit water to enter, they would probably retain their structural characteristics, thereby minimizing the dispersion of particulate radioactive material to the atmosphere (DIRS 147905-Mishima 1998, all). However, the radionuclides carbon-14 and iodine-129 would have a potential for gas transport. Although iodine-129 can exist in a gas phase, DOE expects it would dissolve in the precipitation and migrate in surface water and groundwater. DOE also expects the consequences from a release of carbon-14 to be very small based on the low failure rate of zirconium-clad spent nuclear fuel (see Appendix K, Section K.2.1.4.1 for details) and large atmospheric dilution.

7.2.2.7 Accidents

For Scenario 2, the analysis examined the impacts of an accident scenario that could occur during the above-ground storage of spent nuclear fuel and high-level radioactive waste and concluded that the most severe accident scenarios would be an airplane crash into a concrete storage module. The frequency of such an event was estimated to be 0.0000032 (3 in 1 million) crashes per year.

In Scenario 2, the concrete storage modules would deteriorate with time. DOE concluded that an airplane crash into a degraded concrete storage module would dominate the consequences from external initiating events (see Appendix K, Section K.3.2.1). The analysis evaluated the potential for criticality accidents and concluded that an event severe enough to produce large consequences would be extremely unlikely, and that the consequences would be bounded by the airplane crash consequences. Table 7-8 lists the consequences of an airplane crash on a degraded concrete storage module.

Table 7-8. Estimated consequences of an aircraft crash on a degraded spent nuclear fuel concrete storage module.[a]

Factor	High population site[b]	Low population site[c]
Frequency (per year)	3.2×10^{-6}	3.2×10^{-6}
Collective population dose (person-rem)	26,000	6,100
Latent cancer fatalities	13	3

a. Source: DIRS 103711-Davis, Strenge, and Mishima (1998, p. 11).
b. Within 80 kilometers (50 miles) of site, an average of 330 persons per square mile.
c. Within 80 kilometers of site, an average of 77 persons per square mile.

7.2.2.8 Environmental Justice

Deteriorating facilities, storage containers and packaging, and spent nuclear fuel and high-level radioactive waste could produce adverse effects to the nearby public. Any nearby minority or low-income communities could experience disproportionately high and adverse human health impacts. In addition, financial considerations could make it more difficult for members of any affected minority or low-income populations to obtain uncontaminated resources or to move away from contaminated soils and water. Because subsistence patterns for low-income and minority populations could vary from those of persons not in these groups, any affected low-income and minority populations could be exposed to greater than average doses. The result of differing potentials for exposure could be disproportionately high and adverse impacts to minority or low-income populations.

If the United States determines that it will use continued storage at existing sites for the long-term disposition of spent nuclear fuel and high-level radioactive waste, site-specific analyses of storage facilities would be required to identify if environmental justice issues could result. The Nuclear Regulatory Commission established this approach (DIRS 101899-NRC 1996, p. 9-16). With the assumption of no effective institutional control after about 100 years, potential environmental justice issues identified under Scenario 2 probably would be more severe than those identified under Scenario 1 (see Section 7.2.1.13).

7.2.2.9 Sabotage

For Scenario 2, the storage of spent nuclear fuel and high-level radioactive waste for 10,000 years without institutional control would entail a greater risk of intruder access at the 77 sites than exists under current conditions. Due to the lack of institutional control and degraded facilities, sabotage could result in a release of radionuclides to the environment around the facility. The analysis assumed that safeguards and security measures would not be maintained after approximately the first 100 years. For the remaining

9,900 years of the analysis period, the cumulative risk of intruder attempts would increase. As the *storage containers* degraded, they would become more vulnerable to failure. Any amount of material released from its storage container could contaminate areas with radioactivity. Therefore, the risks of sabotage would increase substantially under this scenario in comparison to Scenario 1.

7.3 Cumulative Impacts for the No-Action Alternative

DOE evaluated the disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the Proposed Action analysis. To provide a direct comparison of impacts with the Proposed Action, the No-Action analysis in Sections 7.1 and 7.2 evaluated the impacts of the continued storage of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste at 72 commercial and 5 DOE sites across the United States. DOE chose the volume of 70,000 MTHM for analysis because the NWPA prohibits the Nuclear Regulatory Commission from approving the emplacement of more than 70,000 MTHM in a first repository until a second repository is in operation. This section describes the results of the analysis of the cumulative impacts of the continued storage at the 77 existing sites of all spent nuclear fuel and high-level radioactive waste (called Inventory Module 1) (Table 7-9). Chapter 8 discusses the cumulative impacts of disposing of radioactive waste at the Yucca Mountain Repository in excess of the Proposed Action repository.

Table 7-9. Inventories for Proposed Action and Module 1.[a]

Material	Proposed Action	Module 1
DOE spent nuclear fuel	2,333 MTHM	2,500 MTHM
Commercial spent nuclear fuel[b]	63,000 MTHM	105,000 MTHM
High-level radioactive waste[b]	8,315 canisters	22,280 canisters

a. Source: Appendix A, Section A.1.1.4.1.
b. Surplus plutonium would be included in the inventory in the form of mixed-oxide fuel (treated as commercial spent nuclear fuel) or immobilized plutonium (high-level radioactive waste).

A cumulative impact is defined as “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions” (40 CFR 1508.7). Cumulative impact assessment is based on both the geographic (spatial) and time (temporal) considerations of past, present, and reasonably foreseeable actions. Geographic boundaries can vary by discipline depending on the time an effect remains in the environment, the extent to which the effect can migrate, and the magnitude of the potential impact. The proximity of other actions to the spent nuclear fuel storage sites is not the only decisive factor for determining the inclusion of an action in the assessment of cumulative impacts. Another, and for this analysis more important, factor is if the other actions would have some influence on the resources in the same time and space affected by continued storage.

The cumulative impacts of past actions have either passed through the environment or are part of existing baseline conditions. For example, the construction impacts of spent nuclear fuel storage facilities will have passed through the environment before the potential impacts associated with continued storage and refurbishment would first be seen in 2002.

DOE based its estimates of the potential impacts from continued storage of commercial spent nuclear fuel on a representative site. The results of the analysis described in the previous section are consistent with the Nuclear Regulatory Commission’s findings in its *Generic Environmental Impact Statement for License Renewal of Nuclear Plants* (DIRS 101899-NRC 1996, pp. 6-85 and 6-86). The NRC stated:

> *The Commission’s regulatory requirements and the experience with on-site storage of spent fuel in fuel pools and dry storage has been reviewed. Within the context of a license renewal review and*

> *determination, the Commission finds that there is ample basis to conclude that continued storage of existing spent fuel and storage of spent fuel generated during the license renewal period can be accomplished safely and without significant environmental impacts. Radiological impacts will be well within regulatory limits; thus radiological impacts of on-site storage meet the standard for a conclusion of small impact. The nonradiological environmental impacts have been shown to be not significant; thus they are classified as small. The overall conclusion for on-site storage of spent fuel during the term of a renewed license is that the environmental impacts will be small for each plant. The need for the consideration of mitigation alternatives within the context of renewal of a power reactor license has been considered, and the Commission concludes that its regulatory requirements already in place provide adequate mitigation incentives for on-site storage of spent fuel.*

Although this finding is applicable only to the continued storage of existing spent nuclear fuel and spent nuclear fuel generated during the 20-year license renewal period for the nuclear powerplant, DOE has concluded that potential environmental and radiological impacts for the storage facility would remain small for much longer periods. Environmental impacts would remain small because no additional fuel would be generated beyond the operation of the nuclear powerplant (plants are assumed to be closed after the first 20-year license renewal period), and radiological impacts would remain within regulatory limits specified in the storage facility license (10 CFR Part 72).

In general, the analysis of cumulative effects can exclude future actions if:

- The action is outside the geographic boundaries or timeframe established for the cumulative effects analysis.
- The action will not affect resources that are the subject of the cumulative effects analysis.
- Including the action would be arbitrary.

Because the estimated impacts would be small, DOE has not attempted to speculate on other arbitrary generic actions that could influence the cumulative impacts generated at a given site. However, the total incremental impact nationally of selected parameters is presented in the preceding section. In addition, the potential impacts at each site do not overlap because the storage sites are located throughout the United States. Therefore, cumulative impacts among the sites on resources would be unlikely.

For the 5 DOE sites, there is a long legacy of EISs and annual monitoring reports. The incremental impacts associated with continued storage of spent nuclear fuel can be added to the results reported in these documents to obtain an estimate of total impacts. For the 72 diverse commercial sites, information on other present and reasonably foreseeable actions varies in terms of data availability and quality. As a consequence, a comparison of cumulative assessments would be problematic, even if the impacts were not as small as the analyses indicate.

The cumulative analysis in this section includes the total projected inventory of commercial spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste (referred to as Module 1) that could come to the repository. Table 7-9 lists the inventories for the Proposed Action analysis and the Module 1 cumulative analysis.

For consistency with the cumulative impact analysis in Chapter 8, the No-Action analysis considered the same spectrum of environmental impacts as the Proposed Action. However, because of the DOE commitment to manage spent nuclear fuel and high-level radioactive waste safely, the Department decided to focus the No-Action cumulative analysis on the short- and long-term health and safety of workers and members of the public. Therefore, quantitative estimates of the cumulative impacts in this section include occupational and public health and safety, waste management, and traffic and transportation. The qualitative discussions of other disciplines are included for completeness.

DOE recognizes that approximately 2,100 cubic meters (74,000 cubic feet) of commercial low-level radioactive waste will exceed Nuclear Regulatory Commission Class C limits (listed in 10 CFR 61.55, Tables 1 and 2 for long and short half-life radionuclides, respectively). This type of waste, called *Greater-Than-Class-C low-level waste*, is generally not suitable for near-surface disposal (see Appendix A, Section A.2.5, for a detailed description). Similarly, DOE low-level radioactive waste that exceeds the Nuclear Regulatory Commission Class C limits (referred to as *Special-Performance-Assessment-Required waste*) will amount to about 4,000 cubic meters (142,000 cubic feet) (see Appendix A, Section A.2.6, for a detailed description). Together these waste types, added to the Module 1 inventory, comprise the Module 2 inventory.

The NWPA does not specifically consider Greater-Than-Class-C or Special-Performance-Assessment-Required wastes. Therefore, DOE has not included either waste type in the Proposed Action inventory for the consideration of potential impacts that could occur from the disposal of spent nuclear fuel and high-level radioactive wastes in a geologic repository at Yucca Mountain. The disposal of these wastes at Yucca Mountain, however, is part of the cumulative impact analysis (see Chapter 8) because the impacts of that disposal are reasonably foreseeable as the results of future actions.

Further, DOE has not included Module 2 in its consideration of potential impacts under the No-Action Alternative. DOE does not have enough information about Module 2 wastes at present to be able to perform a meaningful analysis with respect to the No-Action Alternative. As discussed in Appendix A, Section A.2.5, Greater-Than-Class-C waste could include, for example, certain commercial nuclear powerplant operating and decommissioning wastes and sealed radioisotope sources. DOE Special-Performance-Assessment-Required waste could include certain production reactor operating wastes, production and research reactor decommissioning wastes, sealed radioisotope sources, and isotope production-related wastes (see Appendix A, Section A.2.6). As just one example of the confounding potential sources of these types of wastes, in 1993 DOE estimated that 2,552 Greater-Than-Class-C low-level waste fixed-gauge and X-ray fluorescence sealed sources (general licensees) and 7,582 sealed sources (for example, calibration, medical, well logging sources) were used and stored by private industry at hundreds of locations in the United States (DIRS 101798-DOE 1994, all).

As this example illustrates, a meaningful analysis would need to consider the sites, or combination of sites, at which these waste types are currently in use and storage. The analytic approach used to construct the regional representative sites for which the continued storage of spent nuclear fuel and high-level radioactive waste was evaluated would not apply to the hundreds of additional locations associated with Greater-Than-Class-C and Special-Performance-Assessment-Required wastes.

For the spent nuclear fuel and high-level radioactive waste analysis in this EIS (see Appendix K, Section K.2.1), DOE collected information from published sources for each of the 77 sites where spent nuclear fuel and high-level radioactive waste is located and, to simplify the analysis, divided the country into five regions. The Department then configured a single hypothetical site in each region (see Appendix K, Section K.2.1.6), which enabled it to estimate the potential release rate of the radionuclide inventory from the spent nuclear fuel and high-level radioactive waste, based on forecast interactions of the environment (rainfall, freeze-thaw cycle) with the engineered barrier (concrete storage modules).

Environmental information at the hundreds of sites in which Greater-Than-Class-C and Special-Performance-Assessment-Required wastes are in use and storage is not readily available and DOE could not obtain it without an exorbitant commitment of resources. Relevant environmental evaluations such as those prepared by the Nuclear Regulatory Commission for operating commercial nuclear powerplants or spent nuclear fuel storage installations are not available for most of the locations at which these waste types are in use or storage. Further, the manner in which Greater-Than-Class-C and Special-Performance-Assessment-Required low-level wastes are stored varies by waste types, and the great variety of storage methods could not be simplified for analytical purposes without distorting the resulting potential environmental impacts.

Even if such information were gathered and the means of storage could be reduced by the use of simplifying assumptions, the results of the analysis (the impacts) would tend to reinforce the results of the impact analysis performed for the Module 1 inventory. That is, short-term impacts such as those to socioeconomics and land use would not increase appreciably, but health effects probably would increase over the long term because workers and the public would be exposed to these waste types in addition to spent nuclear fuel and high-level radioactive waste at the many locations across the United States.

7.3.1 SHORT-TERM IMPACTS IN THE YUCCA MOUNTAIN VICINITY

Candidate materials would not be transported to the repository. Therefore, impacts from Module 1 would be the same at the Yucca Mountain site as those presented in Section 7.1.

7.3.2 SHORT- AND LONG-TERM IMPACTS AT COMMERCIAL AND DOE SITES

7.3.2.1 Land Use and Ownership

Under Scenario 1 (long-term institutional control), as discussed in Section 7.2.1.1, the land required for storage facilities typically would be a few acres. For the Module 1 inventory, the analysis assumed that the land required would increase, on average, by about 60 percent (the ratio of Proposed Action and Module 1 inventories). This additional land requirement [less than 0.04 square kilometer (10 acres) per site] would represent a small percentage of the land currently available at the sites; therefore, the incremental impacts on land use would be minimal but larger than those for the Proposed Action facilities. These storage facilities would be on land currently owned by DOE or a utility and, therefore, would be unlikely to affect land ownership.

Under Scenario 2 (assumption of no effective institutional control after about 100 years), as discussed in Section 7.2.2.1, without maintenance and periodic replacement, facilities, storage containers, and the spent nuclear fuel and high-level radioactive waste would begin to deteriorate, eventually contaminating the land surrounding the storage facilities and rendering it unfit for human habitation or agricultural uses for hundreds or thousands of years. The additional inventories of Module 1 probably would increase the concentrations of radioactive materials in the soils and the size of the affected areas over those expected for the Proposed Action inventory. As with the Proposed Action, these concentrations and areas would be difficult to estimate but even with the additional inventories of Module 1, DOE believes it would involve less than several hundred acres at each of the 77 sites.

In addition, as with the Proposed Action, because Scenario 2 assumes no effective institutional control after approximately 100 years, there would not be an orderly conversion of land use and ownership to other uses or ownership. Therefore, the potential for members of the public to move onto storage facility lands with Module 1 inventories would be unchanged from that expected for the Proposed Action.

7.3.2.2 Air Quality

As discussed in Section 7.2.1.2, under Scenario 1 best management practices and effective monitoring procedures would ensure that contaminant releases to the air would be minimal and would not exceed current regulatory limits (40 CFR Part 61 for hazardous air pollutants emissions and Part 50 for air quality standards). In addition, DOE expects that these controls would be effective with the additional inventories of Module 1. Therefore, air quality under Scenario 1, Module 1 would not be adversely affected during routine operations.

As discussed in Section 7.2.1.2, during the construction of replacement facilities, exhaust from construction vehicles would temporarily increase local concentrations of hydrocarbons, carbon monoxide, and oxides of nitrogen for a few years during each 100 years. DOE expects that these temporary increases in particulate matter resulting from construction activities would persist for slightly longer periods because of the additional facilities required to store the additional inventories of Module 1. However, mitigation measures such as watering unpaved roads would limit the generation of fugitive dust. As with the Proposed Action, after replacement the old site would be seeded, graveled, or paved to reduce air emissions. Therefore, although adverse air quality impacts during construction would be slightly higher for the Module 1 inventory, DOE expects them to be minimal and transient.

The Module 1 air quality impacts under Scenario 2, as discussed in Section 7.2.2.2, would be minimal because even degraded facilities would limit the release of radioactive particulate material to the atmosphere.

7.3.2.3 Hydrology

7.3.2.3.1 *Surface Water*

For Scenario 1, as discussed in Section 7.2.1.3.1, under long-term institutional control, best management practices such as stormwater pollution prevention plans and stormwater holding ponds would ensure that, in the unlikely event of an inadvertent release, contaminants would not reach surface-water systems. These controls and monitoring procedures would be effective for the additional inventories of Module 1. Therefore, as with the Proposed Action inventory, surface-water quality would not be adversely affected by routine operations.

For long-term impacts from Scenario 2, after about 100 years when there is an assumption of no effective institutional control, the Module 1 contaminants could enter surface water via stormwater runoff from degraded facilities in quantities greater than those expected for the Proposed Action. Section 7.3.2.7.3 discusses the incremental impacts to the public expected from these additional surface water contaminants resulting from the Module 1 inventory.

7.3.2.3.2 *Groundwater*

Under Scenario 1, Module 1 groundwater impacts from the storage of 105,000 MTHM of commercial spent nuclear fuel, 2,500 MTHM of DOE spent nuclear fuel, and 22,280 canisters of high-level radioactive waste would be minimal because best management practices such as spill prevention and cleanup plans and procedures and effective effluent monitoring procedures would ensure that inadvertent contaminant releases did not reach groundwater.

In addition, although the analysis assumed that the average square footage of storage facilities would increase by about 60 percent for the additional Module 1 inventory, the shallow foundations of these surface structures would not disturb groundwater systems. Some additional DOE storage facilities would be subsurface structures for which construction could require minimal dewatering of the groundwater aquifer. However, the larger square footage of the Module 1 structures would be relatively small (a few acres) in relation to the size of the aquifer, so no adverse impacts would result from dewatering activities.

For long-term impacts from Scenario 2, Module 1 contaminants would be likely to enter the underlying groundwater from degraded facilities in quantities greater than those expected for the Proposed Action. Section 7.3.2.7.3 discusses the incremental impacts to the public from these additional groundwater contaminants resulting from the Module 1 inventory.

7.3.2.4 Biological Resources and Soils

For Scenario 1, as discussed in Section 7.2.1.4, under long-term institutional control, impacts to biological resources or soils from the construction every 100 years and operation of the storage facilities would be minimal for the expanded Module 1 inventory. The facilities necessary to store the expanded Module 1 inventory would be fenced to keep wildlife out and replacement facilities would be constructed on previously disturbed soil. In addition, as with the Proposed Action, spills would be contained and cleaned up immediately, thus minimizing the area of soil affected.

For long-term impacts from Scenario 2, the analysis assumed that the potential for individual animals to be exposed to radiation at the storage sites would increase in proportion to the increased Module 1 inventory in comparison to the Proposed Action inventory (approximately 60 percent). While the increased contaminant exposure could have negative effects, including death, on individual animals, adverse impacts to entire populations would be unlikely because the lethal area surrounding the degraded facilities would be limited to a few hundred acres.

Contamination of soils at the storage facilities by radioactive materials leaching from the spent nuclear fuel and high-level radioactive waste material would be likely to increase in proportion to the increase in Module 1 inventory. Appendix K, Section K.2.4, discusses impacts to members of the public from eating food grown in contaminated soils or livestock fed on such soils.

7.3.2.5 Cultural Resources

For Scenario 1, the analysis assumed that the Module 1 replacement of spent nuclear fuel and high-level radioactive waste storage facilities would increase by about 60 percent over the Proposed Action. However, these additional facilities would generally be on undeveloped land owned by DOE or the commercial utilities in rural areas. As with the Proposed Action, the size of the additional facilities and supporting infrastructure would be small enough that the facility probably would avoid known cultural resources. In addition, if previously unknown archaeological sites, human remains, or funerary objects were uncovered during construction, DOE or the commercial utility would comply with Executive Orders and Federal and state regulations for the protection of cultural resources. Therefore, construction and operations would not affect cultural resources.

For long-term impacts from Scenario 2, construction and operation for about the first 100 years would be as described for Scenario 1. After this time, no construction or operation activities would occur at the generating sites; therefore, cultural resources would not be adversely affected.

7.3.2.6 Socioeconomics

For Scenario 1, the total staff required at 77 sites to monitor, maintain, and replace the Module 1 facilities would increase from about 700 for the Proposed Action inventory of 70,000 MTHM to more than 800 for the Module 1 inventory of 105,000 MTHM (DIRS 104596-Orthen 1999, Table 6). This increase is approximately equivalent to adding no more than two individuals at each of the 77 sites. Therefore, the additional storage requirements of the Module 1 inventory would be unlikely to affect socioeconomic factors such as infrastructure and regional economy.

For long-term impacts from Scenario 2, because there is an assumption of no effective institutional control after about 100 years, there would be no workers for either the Proposed Action or Module 1 inventories. Therefore, the Module 1 socioeconomic impacts would be essentially the same as those for the Proposed Action for the first 100 years, but after that approximately 800 jobs would be lost. Because these jobs would be spread over 72 commercial and 5 DOE sites (about 10 jobs per site), socioeconomic impacts would be very small for a given region.

7.3.2.7 Occupational and Public Health and Safety

7.3.2.7.1 *Nonradiation Exposures*

For Scenario 1, Module 1, as with the Proposed Action, maintenance, repairs, repackaging, and construction at the storage facilities would be conducted in accordance with Occupational Health and Safety Administration and National Institute of Occupational Safety and Health requirements (29 CFR). Worker exposures to industrial nonradioactive hazardous materials during construction and operation of the storage facilities would be minimized through administrative controls and design features such that exposures would remain below hazardous levels.

For long-term impacts from Scenario 2, the increased inventory of Module 1 and resultant increase in stainless steel storage canisters would be likely to result in a proportional increase in concentrations of chemically toxic materials (such as chromium) in the groundwater and surface waters at the storage sites. However, as discussed in Section 7.2.2.5.1, these concentrations would remain extremely low and would not result in adverse human health impacts. In addition, as discussed in Section 7.2.2.5.1, the Department did not attempt to evaluate adverse health impacts resulting from dissolution of chemically toxic waste forms because it did not want to overestimate impacts from the No-Action Alternative.

7.3.2.7.2 *Industrial Hazards*

For Scenario 1, as discussed in Section 7.2.1.7.2, the majority of the industrial accidents would occur as a result of surveillance (about 94 percent) and construction tasks. Operations tasks would contribute less than 0.001 percent of the total number of accidents. Therefore, to estimate the number of industrial accidents that would be likely to occur at the storage sites for the Module 1 inventory, the number of additional concrete storage modules required to store the additional inventory was calculated.

For Module 1 during the approximately 100-year construction and operation cycle (2002 to 2116), about 80,000 full-time equivalent work years would be required to maintain about 11,000 concrete storage modules and 8 below-grade storage vaults at the 77 sites (DIRS 104596-Orthen 1999, Table 1). Based on this level of effort, as listed in Table 7-10, about 2,800 industrial safety incidents would be likely, resulting in about 1,200 lost workday cases and 3 fatalities (an average of about 1 fatality every 30 years).

Table 7-10. Estimated Module 1 industrial safety impacts at commercial and DOE sites during the first 100 years and the remaining 9,900-year period of analysis under Scenario 1.[a]

Industrial safety impacts	Short-term (100 years)[b] construction and operation	Long-term (9,900 years)[c] construction and operation
Total recordable cases	2,800	410,000
Lost workday cases	1,200	180,000
Fatalities	3	490

a. Source: DIRS 104596-Orthen (1999, Tables 6 and 7).
b. The estimated impacts would result from a single 100-year period of storage module construction (renovation), operation, surveillance, and maintenance.
c. Period from 100 to 10,000 years.

In addition, for Module 1, Table 7-10 indicates about 410,000 projected industrial safety incidents, of which about 180,000 would be lost workday cases and 490 would involve fatalities (an average of about 1 fatality every 20 years or about 1 every 1,600 years at each of the 77 sites). Surveillance tasks would provide about 94 percent of the total worker level of effort, construction tasks would provide nearly all of the remaining 6 percent, and operations tasks would provide less than 0.001 percent.

7.3.2.7.3 *Radiation Exposures*

For Scenario 1, radiation exposures to offsite populations, involved workers, and noninvolved workers would increase because of the additional Module 1 inventory and the construction of additional facilities required to store the materials. The analysis assumed that radiation exposures to offsite and noninvolved worker individuals would increase by the ratio of the Module 1 inventory to the Proposed Action inventory, a factor of about 1.7. Radiation dose rates for the involved maximally exposed worker (construction) would not increase because of the self-shielding effect of the concrete storage modules. Table 7-11 lists radiological human health impacts resulting from the Module 1 inventory.

Table 7-11. Estimated Module 1 radiological human health impacts for Scenario 1.[a]

Receptor	Short-term (100 years) construction and operation	Long-term (9,900 years) construction[b] and operation
Population[c]		
MEI[d] (millirem per year)	0.34	0.10
Dose[e] (person-rem)	1,400	8,800
LCFs[f]	0.70	4.4
Involved workers[g]		
MEI[h] (millirem per year)	170	50
Dose (person-rem)	4,700	41,000
LCFs	1.9	16
Noninvolved workers[i]		
MEI[j] (millirem per year)	23	0[k]
Dose (person-rem)	61,000	0[k]
LCFs	25	0[k]

a. Source: Adapted from DIRS 101898-NRC (1991, all); DIRS 104596-Orthen (1999, all).
b. Assumes construction of 11,000 concrete storage modules, 1 above-grade vault, and 8 below-grade vaults at 77 sites (DIRS 104596-Orthen 1999, Table 1) every 100 years.
c. Members of the general public living within 3 kilometers (2 miles) of the facilities; estimated to be 140,000 over the first approximately 100 years and approximately 14 million over the 9,900-year long-term analysis period [estimated using DIRS 102204-Humphreys, Rollstin, and Ridgely (1997, all)].
d. MEI = maximally exposed individual; assumed to be approximately 1.4 kilometers (0.8 mile) from the center of the storage facility (DIRS 101898-NRC 1991, p. 22).
e. Estimated doses account for radioactive decay.
f. LCF = latent cancer fatality; expected number of cancer fatalities for populations. Based on a risk of 0.0004 and 0.0005 latent cancer per rem for workers and members of the public, respectively (DIRS 101857-NCRP 1993, p. 112), and a life expectancy of 70 years for a member of the public and a 50-year career for workers.
g. Involved workers would be those directly associated with construction and operation activities (DIRS 101898-NRC 1991, pp. 23 to 25). For this analysis, the involved worker population would be about 1,600 individuals (800 individuals at any one time) at 77 sites over 100 years (DIRS 104596-Orthen 1999, Table 6). This population would grow to more than 190,000 over 10,000 years.
h. Based on maximum construction dose rate of 0.11 millirem per hour and 1,500 hours per year (DIRS 101898-NRC 1991, p. 23).
i. Noninvolved workers would be employed at the powerplant but would not be associated with facility construction or operation. For this analysis, the noninvolved worker population would be 80,000 individuals who would receive exposure until the powerplants were decommissioned (50 years).
j. Based on a projected area workforce of 1,200 and an average estimated annual dose of 16 person-rem (DIRS 101898-NRC 1991, p. 24).
k. During this period the powerplants would have ended operation, so there would be no noninvolved workers.

As listed in Table 7-11, the estimated dose to the hypothetical maximally exposed offsite individual for the Module 1 inventory during the operational period between 2002 and 2116 would be about 0.34 millirem per year [adapted from DIRS 101898-NRC (1991, p. 22)]. For the remaining 9,900 years of the analysis period, the dose to the hypothetical maximally exposed individual would decrease to about 0.10 millirem per year because of radioactive decay of the source material. During about the first

100 years, the dose (accounting for radioactive decay) could result (over a 70-year lifetime of exposure) in an increase in the lifetime risk of contracting a fatal cancer of 0.0000073, an increase over the lifetime natural fatal cancer incidence rate of 0.0031 percent. During the remaining 9,900 years of the analysis period, the dose (accounting for radioactive decay) could result (over a 70-year lifetime of exposure) in an increase in the lifetime risk of contracting a fatal cancer of 0.0000022, an increase over the lifetime natural fatal cancer incidence rate of 0.00092 percent.

For the short-term impacts, over about the first 100 years the offsite exposed population of approximately 140,000 would be likely to receive a total collective dose of 1,400 person-rem (adjusted for radioactive decay). This dose could result in 0.70 latent cancer fatality in addition to the 33,000 fatal cancers likely in the exposed population from all other causes. This represents an increase of about 0.0021 percent over the estimated number of cancer fatalities that would occur in the exposed population from all other causes.

For the long-term impacts from Scenario 1, the radiation dose of 8,800 person-rem from the storage facilities could result in an additional 4.4 latent cancer fatalities in the surrounding population of about 14 million. This would be in addition to about 3.3 million cancer fatalities that would be likely to occur in the exposed population of 14 million, an increase of 0.00013 percent over the natural incidence rate.

The analysis assumed the maximally exposed individual in the involved worker population would be a construction worker involved with construction and loading of replacement facilities. Assuming a maximum dose rate of 0.11 millirem per hour (unchanged from the Proposed Action) and an average exposure time of 1,500 hours per year, this construction worker would receive about 170 millirem per year. During about the first 100 years, this dose could result (over three years of construction) in an increase in the lifetime risk of contracting a fatal cancer of 0.00020, an increase of 0.09 percent over the natural fatal cancer incidence rate. During the remaining 9,900 years of the analysis period, the dose could result (over three years of construction) in an increase in the risk of contracting a fatal cancer of 0.000060, an increase over the natural fatal cancer incidence rate of 0.03 percent.

For the involved worker population of 1,600 individuals, approximately 380 would be likely to contract a fatal cancer from some cause other than occupational exposure. In the involved population of 1,600 storage facility workers (during the first 100 years), the collective dose of 4,700 person-rem (corrected for radioactive decay) between 2002 and 2116 could result in 1.9 additional latent cancer fatalities (DIRS 104596-Orthen 1999, Table 6), which would result in an increase of 0.51 percent over the natural incidence rate of fatal cancers from all causes. During the remaining 9,900 years of the analysis period, the involved estimated worker population of more than 190,000 would receive a collective dose of about 41,000 person-rem (corrected for radioactive decay). This dose could result in 16 latent cancer fatalities in addition to the 45,000 cancer fatalities that would be likely in the exposed population from all other causes. These additional cancers would represent an increase of 0.036 percent over the natural incidence rate of fatal cancers.

The estimated Module 1 collective dose to noninvolved workers at a nuclear powerplant from the Module 1 inventory would be about 27 person-rem per year [adapted from DIRS 101898-NRC (1991, p. 24)] for the protected area workforce of 1,200 individuals (DIRS 101898-NRC 1991, p. 26) at the two-unit station at Calvert Cliffs. This collective dose would result in an average maximum dose to the noninvolved worker of 23 millirem per year. Over a 50-year career, this exposure (corrected for radioactive decay) could result in an increase in the lifetime risk of contracting a fatal cancer of 0.00032. This incremental increase in risk would represent an increase of 0.13 percent over the incidence of fatal cancers from all other causes.

In the total noninvolved worker population of 80,000 powerplant workers (all sites), the estimated Module 1 collective dose of 61,000 person-rem (corrected for decay) between 2002 and 2116 could result in 25 additional latent cancer fatalities. This increase represents about an 0.13-percent increase over the 19,000 cancer fatalities that would be likely to occur from all other causes in the same worker population.

After about 100 years, Scenario 2 assumes no effective institutional control of the 77 sites and assumes that the storage facilities would be abandoned. Therefore, there would be no health risk for workers during that period. For the long-term impacts from Scenario 2, the analysis estimated human health impacts to the public on a regional basis (DIRS 104924-Poe 1999, p. 15). The estimated total population dose would increase from 6.6 million person-rem to about 7.3 million person-rem, resulting in an increase in the number of latent cancer fatalities from about 3,300 to almost 3,700 over the 9,900-year analysis period. Appendix K (Sections K.2.4.1 and K.3.1) contains details of the Proposed Action analysis.

7.3.2.8 Accidents

For Scenario 1, both short- and long-term accident consequences for the additional inventory of Module 1 would be bounded by the severe seismic event and could result in slightly higher impacts than those predicted for the Proposed Action inventory. However, this accident scenario would probably produce only minor radiological impacts to persons in the immediate vicinity of the storage facility.

For Scenario 2, the long-term impacts for Module 1 would be the same as those for the Proposed Action (see Section 7.2.2.7) because only a single concrete storage module would be affected, regardless of inventory.

7.3.2.9 Noise

For Scenario 1, noise levels for the Module 1 inventory should not be noticeably greater than those for the Proposed Action. Therefore, the noise would not adversely affect the hearing of facility workers or frighten wildlife from the area.

For the long-term impacts from Scenario 2, as with the Proposed Action, no noise would emanate from the facilities; therefore, no adverse impacts would occur. For about the first 100 years, noise levels would be the same as those for Scenario 1.

7.3.2.10 Aesthetics

As for the Proposed Action, Scenario 1 impacts to aesthetic or scenic resources from storage facilities resulting from the Module 1 inventory would be unlikely. Though the inventory would be larger than that for the Proposed Action, Module 1 would still require only two adjacent locations at each site. Every 100 years, a new facility would be constructed on the idle site, and the storage containers would be transferred. The old facility would be demolished and the site would remain idle for the next 100 years.

For the long-term impacts from Scenario 2, aesthetics would not change until facilities began to degrade, at which time the aesthetic value of the sites would change.

7.3.2.11 Utilities, Energy, and Materials

For Scenario 1, decommissioning and reclamation activities every 100 years associated with the increased number of concrete storage modules required for the Module 1 inventory would consume slightly more diesel fuel, gasoline, and materials than those for the Proposed Action. However, as with the Proposed Action, much equipment and many materials would be salvaged and recycled. DOE would recycle building materials as practicable. Minimal surveillance activities would require some gasoline. Therefore, the increased Module 1 inventory would not adversely affect the utility, energy, or material resources of the region or the country.

For the long-term impacts from Scenario 2, as with the Proposed Action, DOE would not use utilities, energy, or materials after about 100 years and, therefore, impacts to these resources would be unlikely.

7.3.2.12 Waste Management

Under Scenario 1, the construction of new facilities and the demolition of old facilities every 100 years (and the one-time refurbishment of existing facilities after the first 50 years) would generate construction debris and sanitary and industrial solid waste. In addition, routine repairs and maintenance to the facilities and storage containers, routine radiological surveys, and overpacking of failed containers would generate sanitary and industrial solid and low-level radioactive wastes. Because there would not be a dedicated workforce at the storage facilities, only small amounts of sanitary wastes would be generated except during periods of construction. The greatest amount of waste would be generated during the demolition of facilities at the 72 commercial and 5 DOE storage sites every 100 years. The demolition of facilities once every 100 years at all the sites would generate, on average, an estimated 1.4 million cubic meters (1.8 million cubic yards) of nonhazardous demolition debris, recyclable steel, and potentially a small amount of low-level waste if a dry storage canister failed while in storage (DIRS 104596-Orthen 1999, Table 7). The debris and wastes would be disposed of at commercial or DOE disposal facilities across the Nation. The impacts to available capacity would be spread nationwide, thus minimizing impacts to a single disposal facility. The capacities of the disposal facilities would accommodate the wastes generated at the storage facilities.

For Scenario 2, demolition activities would terminate after about 100 years and, therefore, no additional long-term waste management impacts would be likely after this period.

7.3.2.13 Environmental Justice

For Scenario 1, the potential impacts of continued storage of the Module 1 inventory with institutional control would be minimal. Therefore, minority or low-income populations would not be disproportionately or adversely affected.

For the long-term impacts from Scenario 2, the increased number of facilities required to store the Module 1 inventory could adversely affect the nearby public to a degree greater than that for the Proposed Action inventory. As with the Proposed Action inventory, nearby minority or economically disadvantaged communities could experience disproportionately high and adverse human health impacts. In addition, financial considerations could make it more difficult for members of minority or low-income populations to obtain uncontaminated resources or to move away from contaminated soils and water. Because subsistence patterns vary for minority or low-income populations, members of these populations could be exposed to greater than average doses. The result of differing potentials for exposure could result in disproportionately high and adverse impacts to minority or low-income populations.

7.3.2.14 Traffic and Transportation

For Scenario 1, the estimated number of workers commuting to and from work would increase from about 700 to about 800 (DIRS 104596-Orthen 1999, Table 7). The analysis assumed that the number of personnel required for round-the-clock surveillance would not increase but would remain at two individuals per shift per site.

The estimated number of traffic fatalities, which DOE calculated using the assumptions of Section 7.2.1.14, would be approximately 7 for the first 100 years and would increase from about 730 to about 900 for the remaining 9,900 years (DIRS 104596-Orthen 1999, Table 7).

For about the first 100 years, there would be no fatalities from exhaust emissions because there would be no construction or demolition of facilities. For the remaining 9,900 years, trucks would travel over 2.2 billion kilometers (1.4 billion miles), resulting in approximately 31 prompt traffic fatalities (DIRS 103455-Saricks and Tompkins 1999, Table 4, p. 25) and about 0.2 latent fatality from vehicle exhaust emissions.

The long-term impacts from Scenario 2 would be the same as those estimated for the first 100 years under Scenario 1 for Module 1. After the first 100 years, there would be no traffic or transportation-related impacts because all activity would cease.

7.3.2.15 Sabotage

For Scenarios 1 and 2, the risk of intruder access at each of the 77 sites would be essentially the same for Module 1 as for the Proposed Action inventory because the number of sites would remain the same. Therefore, the difficulty of maintaining 77 sites over 100 or 10,000 years also would remain essentially unchanged.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

148091	BLS 1998	BLS (Bureau of Labor Statistics) 1998. "Safety and Health Statistics, Table 1. Incidence Rates of Nonfatal Occupational Injuries and Illnesses by Selected Industries and Case Types, 1997." Washington, D.C.: U.S. Department of Commerce. Accessed December 18, 1998. http://stats.bls.gov/news.release/osh.t01.htm. TIC: 243569.
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103173	Clinch River 1985	Clinch River MRS Task Force 1985. *Recommendations on the Proposed Monitored Retrievable Storage Facility.* DOE/OR/21555-T4. Washington, D.C.: U.S. Department of Energy. TIC: 235908.
103177	CP&L 1989	CP&L (Carolina Power and Light Company) 1989. *Brunswick Steam Electric Plant Independent Spent Fuel Storage Installation Safety Analysis Report.* Raleigh, North Carolina: Carolina Power and Light Company. TIC: 3933.

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101911	Poe 1998	Poe, W.L., Jr. 1998. *Regional Binning for Continued Storage of Spent Nuclear Fuel and High-Level Wastes.* Las Vegas, Nevada: Jason Technologies. TIC: 244049.
104924	Poe 1999	Poe, W.L., Jr. 1999. *Long Term Environmental Analysis of Total Inventory of Spent Nuclear Fuel and High-Level Waste for No-Action Alternative of Yucca Mountain Environmental Impact Statement.* Aiken, South Carolina: Tetra Tech NUS. ACC: MOL.19990513. 0042.
101917	Rollins 1998	Rollins, E.M. 1998. *Evaluation of Multimedia Environmental Transport Models for Use in the Yucca Mountain Environmental Impact Statement No-Action Alternative.* Aiken, South Carolina: Tetra Tech NUS. ACC: MOL.20001010.0213.
103455	Saricks and Tompkins 1999	Saricks, C.L. and Tompkins, M.M. 1999. *State-Level Accident Rates of Surface Freight Transportation: A Reexamination.* ANL/ESD/TM-150. Argonne, Illinois: Argonne National Laboratory. TIC: 243751.
101935	Toblin 1999	Toblin, A.L. 1999. *Radionuclide Transport and Dose Commitment from Drinking Water from Continued Storage and Degradation of Spent Nuclear Fuel and High-Level Waste Materials Under Loss of Institutional Control.* Gaithersburg, Maryland: Tetra Tech NUS. TIC: 244116.

102188	YMP 1995	YMP (Yucca Mountain Site Characterization Project) 1995. *Reclamation Implementation Plan.* YMP/91-14, Rev. 1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19970109.0256. In the Draft EIS, this reference was cited as DOE 1995 in Chapter 12.

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8. CUMULATIVE IMPACTS

The Council on Environmental Quality regulations that implement the procedural provisions of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 *et seq.*), define a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). The term reasonably foreseeable refers to future actions for which there is a reasonable expectation that the action could occur, such as a proposed action under analysis, a project that has already started, or a future action that has obligated funding. Cumulative impacts can result from individually minor but collectively important actions taking place over a period of time. An evaluation of cumulative impacts is necessary to an understanding of the environmental implications of implementing the Proposed Action and is essential to the development of appropriate mitigation measures and the monitoring of their effectiveness.

DOE structured the cumulative impact assessments in this chapter by identifying actions that could have effects that coincided in time and space with the effects from the proposed repository and associated transportation activities. The identification of the relevant actions was based on reviews of resource, policy, development, land-use plans prepared by agencies at all levels of government and from private organizations, other environmental impact statements, environmental assessments, and Native American tribal meeting records. Consistent with Council on Environmental Quality regulations 40 CFR 1502.16(c) and 1506.2, in addition to the assessment of potential cumulative impacts, the analysis considered potential conflicts with plans issued by various governmental entities to the extent practicable and to the extent they provided relevant information.

Not all actions identified in this chapter would have cumulative impacts in all discipline areas. Potential impacts for such actions are discussed for the appropriate discipline areas. In some instances for which an action is reasonably foreseeable, quantitative estimates of impacts are not possible because the action is in its early stages. For those actions, DOE acknowledges the project and states that potential cumulative impacts are unknown at this time.

This chapter evaluates the environmental impacts of repository activities coupled with the impacts of other Federal, non-Federal, and private actions. As part of this process, the chapter includes a detailed analysis of nuclear materials in need of permanent disposal in excess of those evaluated in the Proposed Action. It describes and evaluates these waste quantities, referred to as Inventory Modules 1 and 2, evaluated in terms of their environmental impacts in comparison with those of the Proposed Action impacts. The evaluation of these inventories provides sufficient information for future actions and decisionmaking on inventory selection. This chapter evaluates cumulative short-term impacts from the construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain, and cumulative long-term impacts following repository closure. It also evaluates cumulative transportation impacts from the shipment of spent nuclear fuel and high-level radioactive waste to the repository and of other material to or from the repository. The analysis of cumulative transportation impacts includes the possible construction and operation in Nevada of a branch rail line, or of an intermodal transfer station along with highway improvements for heavy-haul trucks. In addition, the analysis considers cumulative impacts from the manufacturing of repository components.

The cumulative impact analysis in this chapter includes as a reasonably foreseeable future action the disposal in the proposed Yucca Mountain Repository of the total projected inventory of commercial spent nuclear fuel, U.S. Department of Energy (DOE) spent nuclear fuel, and high-level radioactive waste, as well as the disposal of commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste. The total projected inventory of spent nuclear fuel and high-level radioactive waste is more than the 70,000 metric tons of heavy metal (MTHM) considered for the

Proposed Action. Its emplacement at Yucca Mountain would require legislative action by Congress unless a second licensed repository was in operation.

There were several reasons to evaluate the potential for disposing of Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste at Yucca Mountain as reasonably foreseeable actions. First, because both materials exceed Class C limits for specific radionuclide concentrations as defined in 10 CFR Part 61, they are generally unsuitable for near-surface disposal. Second, the U.S. Nuclear Regulatory Commission specifies in 10 CFR 61.55(a)(2)(iv) the disposal of Greater-Than-Class-C waste in a repository unless the Commission approved of disposal elsewhere. Finally, during the scoping process for this environmental impact statement (EIS), several commenters requested that DOE evaluate the disposal of other radioactive waste types that might require isolation in a repository. The disposal of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes at the proposed Yucca Mountain Repository could require a determination by the Nuclear Regulatory Commission that these wastes require permanent isolation. In addition to spent nuclear fuel, high-level radioactive waste, surplus plutonium, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste (materials such as depleted uranium), other radioactive wastes could be considered in the future for disposal in the Yucca Mountain Repository.

By analyzing the emplacement of Inventory Module 1 or 2, DOE is not stating that the emplacement of materials beyond those prescribed for the Proposed Action would occur. Rather, the Department is being prudent in analyzing a reasonably foreseeable action that could take place. If a future decision was made to emplace additional material included in the Inventory Modules, the Department would ensure that appropriate National Environmental Policy Act reviews were performed.

In general, the analysis of cumulative impacts in this chapter follows the process recommended in the Council on Environmental Quality's handbook *Considering Cumulative Effects Under the National Environmental Policy Act* (DIRS 103162-CEQ 1997, all). This process includes the identification, through research and consultations, of Federal, non-Federal, and private actions with possible effects that would be coincident with those of the Proposed Action on resources, ecosystems, and human communities. Coincident effects would be possible if the geographic and time boundaries for the effects of the Proposed Action and past, present, and reasonably foreseeable future actions overlapped. Using the methods and criteria described in Chapters 4, 5, and 6 of this EIS and their supporting appendixes, DOE assessed the potential cumulative impacts of coincident effects.

This chapter has six sections. Section 8.1 identifies and analyzes past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action. Sections 8.2 and 8.3 present the analyses of cumulative short-term (the period before the completion of repository closure) and long-term (the first 10,000 and first 1 million years following closure) impacts, respectively, in the proposed Yucca Mountain Repository region. Section 8.4 describes cumulative transportation impacts, nationally and in Nevada. Section 8.5 addresses cumulative impacts associated with the manufacturing of repository components. Section 8.6 presents an overall summary of potential cumulative impacts by discipline area.

8.1 Past, Present, and Reasonably Foreseeable Future Actions

This section identifies past, present, and reasonably foreseeable future actions with impacts that could combine with impacts of the Proposed Action. It describes these actions and their relationships to the Proposed Action that could result in cumulative impacts (see Table 8-1 for a summary). Sections 8.2 through 8.5 present the cumulative impacts from the past, present, and reasonably foreseeable future actions identified in this section.

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Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 1 of 3).

Name and action description	Potential cumulative impact areas: Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Past and present actions[b]				
Nevada Test Site				
Nuclear weapons testing, waste management, etc.	Air quality and public health and safety[b]	Air quality, groundwater, and public health and safety	Occupational and public radiological health and safety	None
Beatty Waste Disposal Area				
Low-level radioactive and hazardous waste disposal	None	Groundwater and public health and safety	Occupational and public radiological health and safety	None
Reasonably foreseeable future actions				
Inventory Module 1[c]				
Disposal of all spent nuclear fuel and high-level radioactive waste in the proposed Yucca Mountain Repository	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)
Inventory Module 2[c]				
Disposal of all spent nuclear fuel and high-level radioactive waste, as well as Greater-Than-Class C waste and Special-Performance-Assessment-Required waste, in the proposed Yucca Mountain Repository	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)	Same resource areas as the Proposed Action (see Table 8-5)
Nellis Air Force Range				
National testing and training for military equipment and personnel	None	None	Land use	None
Nevada Test Site				
Defense (stockpile stewardship and management, material disposition, nuclear emergency response), waste management, environmental restoration, nondefense research and development, work for others	Air quality, groundwater, socioeconomics, public health and safety. (Note: The accident analysis of potential external events in Appendix H addresses the effects of possible future resumption of nuclear weapons tests).	Groundwater and public health and safety	Occupational and public radiological health and safety	None
Nevada Test Site				
Alternative Energy Generation Facility	*Land use, utilities*	None	None	None
DOE Complex-Wide Waste Management Activities Affecting the Nevada Test Site				
Treatment, storage, and disposal of low-level radioactive waste, mixed waste, transuranic waste, high-level radioactive waste, and hazardous waste from past and future nuclear defense and research activities	No additional[d] beyond those analyzed for Nevada Test Site activities	Groundwater and public health and safety	Occupational and public radiological health and safety	None

Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 2 of 3).

	Potential cumulative impact areas			
Name and action description	Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Reasonably foreseeable future actions (continued)				
Low-Level Waste Intermodal Transfer Station				
Construction and operation of an intermodal transfer station for the shipment of low-level radioactive waste to the Nevada Test Site near Caliente	None	None	Same resource areas as the Proposed Action (see Table 8-5) (Caliente intermodal transfer station and highway route for heavy-haul trucks)	None
Timbisha Shoshone Reservation				
Creation and development of a discontiguous reservation in eastern California and southwestern Nevada	Land use, groundwater	None	Water consumption, land use, public safety, environmental justice	None
Cortez Pipeline Gold Deposit Projects				
Continued operation and potential expansion of a gold mine and processing facility	None	None	Land use and ownership (Carlin rail corridor)	None
Apex Bulk Commodities Intermodal Transfer Station				
Construction and operation of an intermodal transfer station for copper concentrate near Caliente	None	None	Same resource areas as the Proposed Action (see Table 8-5) (Caliente intermodal transfer station and highway route for heavy-haul trucks)	None
Shared use of a DOE branch rail line				
Increase in rail operations and traffic resulting from rail service options for nearby mine operators and communities	None	None	Same resource areas as the Proposed Action (see Table 8-5)	None
Private Fuel Storage				
Temporary storage of spent nuclear fuel at the Goshute Reservation in Utah	None	None	Occupational and public radiological health and safety	None
Owl Creek Energy Project				
Temporary storage of spent nuclear fuel	None	None	Potential occupational and public radiological health and safety	None
Ivanpah Airport				
Construction of an airport on previously undisturbed land	None	None	Land use (Jean transportation corridor)	None
Moapa Paiute Energy Center				
Lease land and water use for construction of a coal-fired powerplant	None	None	Land use	None

Table 8-1. Past, present, and reasonably foreseeable future actions that could result in cumulative impacts (page 3 of 3).

Name and action description	Potential cumulative impact areas: Short-term (Section 8.2)	Long-term (Section 8.3)	Transportation (Section 8.4)[a]	Manufacturing (Section 8.5)
Reasonably foreseeable future actions (continued)				
Southern Nevada Public Land Management Act				
Convey approximately 110 square kilometers[e] of Bureau of Land Management lands to commercial and private entities	Land use and ownership	None	Land use and ownership	None
Desert Space Station Science Museum				
Construct an 8,800-square-meter[f] science museum on land acquired from the Bureau of Land Management	Land use	None	None	None

a. In addition to the specific actions identified in Section 8.1 and summarized in this table, the cumulative impacts for national transportation consider the occupational and public radiological health impacts of other past, present, and reasonably foreseeable future shipments of radioactive material.
b. The impacts of most past and present actions are included in the existing environmental baseline described in Chapter 3 and, therefore, are generally encompassed in the analysis of potential impacts of the Proposed Action in Chapters 4, 5, and 6. This includes site characterization activities at Yucca Mountain.
c. As described in Section 8.1.2.1, there would be essentially no difference in the design and operation of the repository for Inventory Module 1 or 2. Therefore, the cumulative impacts from Inventory Module 1 are generally considered the same as those from Inventory Module 2.
d. DOE waste management activities at the Nevada Test Site are included for the continuation of waste management activities at current levels, plus additional wastes that could be received as a result of decisions based on the Waste Management Programmatic EIS (DIRS 101816-DOE 1997, all). This includes cumulative impacts of transportation and disposal.
e. 110 square kilometers = 27,000 acres.
f. 8,800 square meters = 95,000 square feet.

8.1.1 PAST AND PRESENT ACTIONS

The description of existing (baseline) environmental conditions in Chapter 3 includes the impacts of most past and present actions on the environment that the Proposed Action would affect. This includes site characterization activities at Yucca Mountain. The impacts of past and present actions are, therefore, generally encompassed in the Chapter 4, 5, and 6 analyses of potential environmental impacts of the Proposed Action because the baseline for these analyses is the affected environment described in Chapter 3.

Two past actions that are not addressed in the Chapter 3 environmental baseline were identified for inclusion in the cumulative impact analysis in Sections 8.2, 8.3, and 8.4—past DOE activities at the Nevada Test Site (nuclear weapons testing, etc.) and past disposal of low-level radioactive waste at the Beatty Waste Disposal Area. Resources identified where past Nevada Test Site activities could add to impacts from the Proposed Action include air quality, groundwater, public health and safety, and transportation. For the Beatty Waste Disposal Site, the analysis included potential cumulative impacts from past transportation of waste to the Beatty site and from potential groundwater contamination.

Other actions that are presently occurring also have a component that is reasonably foreseeable as a future action. These are discussed in Section 8.1.2.

8.1.2 REASONABLY FORESEEABLE FUTURE ACTIONS

This section describes the reasonably foreseeable future actions that the cumulative impacts analysis considered. The analysis included cumulative impacts from the disposal in the proposed repository of all projected spent nuclear fuel and high-level radioactive waste as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste as reasonably foreseeable future actions (Inventory Modules 1 and 2; see Section 8.1.2.1). Sections 8.1.2.2 and 8.1.2.3 describe other Federal, non-Federal, and private actions that could result in cumulative impacts. This chapter does not discuss cumulative impacts for the No-Action Alternative. Chapter 7, Section 7.3, describes those impacts. Chapters 2 and 7 contain details on the No-Action Alternative and on continued storage of the material at its current locations or at one or more centralized location(s).

DOE gathered information on Federal, non-Federal, and private actions to identify reasonably foreseeable future actions that could combine with the Proposed Action to produce cumulative impacts. The types of documents reviewed included other EISs, resource management plans, environmental assessments, Notices of Intent, Records of Decision, etc. Consultations with Federal agencies, state and local agencies, and Native American tribes (see Appendix C) also contributed to the information used in the cumulative impact analysis.

8.1.2.1 Inventory Modules 1 and 2

Under the Proposed Action, DOE would emplace in the proposed Yucca Mountain Repository as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. Of the 70,000 MTHM, approximately 63,000 MTHM would be commercial spent nuclear fuel. The remaining 7,000 MTHM would consist of approximately 2,333 MTHM of DOE spent nuclear fuel and approximately 8,315 canisters (4,667 MTHM) containing solidified high-level radioactive waste (commercial and defense-related). To determine the number of canisters of high-level radioactive waste included in the Proposed Action waste inventory, DOE used an equivalence of 2.3 MTHM per canister of commercial high-level radioactive waste and 0.5 MTHM per canister of defense high-level radioactive waste as discussed in Appendix A, Section A.2.3.1. DOE has consistently used the 0.5-MTHM-per-canister equivalence since 1985. Using a different approach would change the number of canisters of high-level radioactive waste analyzed for the Proposed Action. Regardless of the number of canisters, the impacts from the entire inventory of high-level radioactive waste are analyzed in this chapter. In addition, the 70,000 MTHM inventory would include an amount of surplus plutonium as spent mixed-oxide fuel or immobilized plutonium.

Inventory Modules 1 and 2 represent the reasonably foreseeable future actions of disposing of all projected commercial and DOE spent nuclear fuel and all high-level radioactive waste as well as Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in the proposed repository (see Figure 8-1). Under Inventory Module 1, DOE would emplace all projected commercial spent nuclear fuel (about 105,000 MTHM), all DOE spent nuclear fuel (about 2,500 MTHM), and all high-level radioactive waste (approximately 22,280 canisters). Inventory Module 2 includes the Module 1 inventory plus other radioactive material that could require disposal in a monitored geologic repository (commercial Greater-Than-Class-C waste and DOE Special-Performance-Assessment-Required waste). The estimated quantities of these other wastes are about 2,000 cubic meters (71,000 cubic feet) and about 4,000 cubic meters (140,000 cubic feet), respectively. Appendix A contains further details on these inventories.

The following paragraphs summarize the differences in repository facilities and operations to receive, package, and emplace the additional materials in Inventory Module 1 or 2. The information on Modules 1 and 2 in this section is from CRWMS M&O (DIRS 104508-1999, DIRS 104523-1999, and DIRS 102030-1999) unless otherwise noted. Table 8-2 summarizes the increased number of shipments that would be required to transport the Module 1 or 2 inventory to the repository. As for the Proposed Action, the estimated numbers of shipments were based on the characteristics of the materials, shipping capabilities at the commercial nuclear sites and DOE facilities, the assumption that there would be one shipping cask per truck or railcar (a train would normally use multiple rail cars and ship more than one

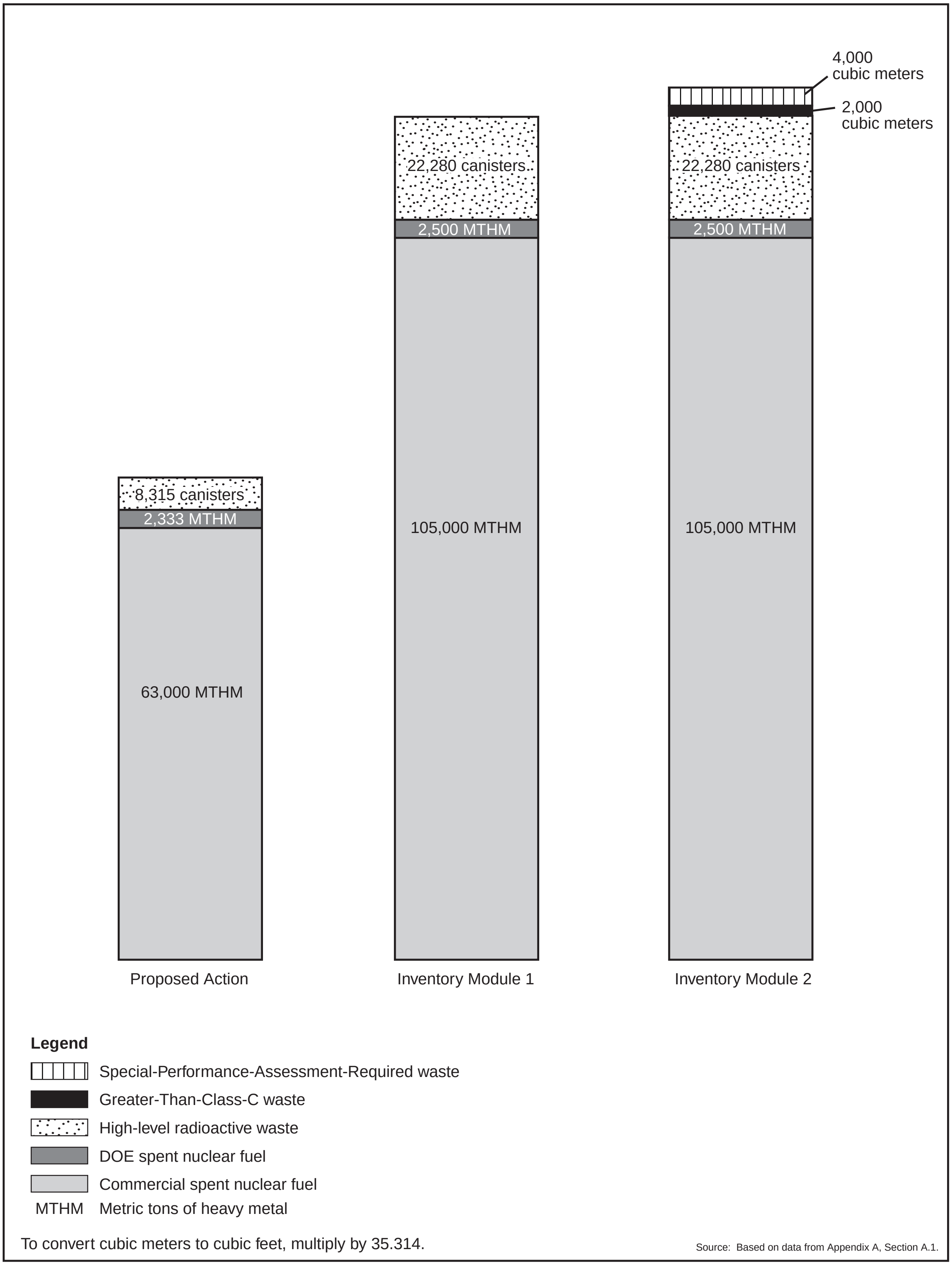

Figure 8-1. Proposed Action, Module 1, and Module 2 inventories evaluated for emplacement in a repository at Yucca Mountain.

Table 8-2. Estimated number of shipments for the Proposed Action and Inventory Modules 1 and 2.[a,b]

Material	Proposed Action: Mostly legal-weight truck: Truck	Proposed Action: Mostly legal-weight truck: Rail[c]	Proposed Action: Mostly rail: Truck	Proposed Action: Mostly rail: Rail	Module 1: Mostly legal-weight truck: Truck	Module 1: Mostly legal-weight truck: Rail	Module 1: Mostly rail: Truck	Module 1: Mostly rail: Rail	Module 2: Mostly legal-weight truck: Truck	Module 2: Mostly legal-weight truck: Rail	Module 2: Mostly rail: Truck	Module 2: Mostly rail: Rail
Commercial SNF[d]	41,000	0	1,100	7,200	80,000	0	3,100	13,000	80,000	0	3,100	13,000
DOE SNF	3,500	300	0	770	3,700	300	0	800	3,700	300	0	800
HLW[e]	8,300	0	0	1,700	22,000	0	0	4,500	22,000	0	0	4,500
GTCC[f] waste	0	0	0	0	0	0	0	0	1,100	0	0	280
SPAR[g] waste	0	0	0	0	0	0	0	0	1,800	55	0	410
Totals	***53,000***	***300***	***1,100***	***9,700***	***110,000***	***300***	***3,100***	***18,000***	***109,000***	***360***	***3,100***	***19,000***

a. Source: Appendix J, Section J.1.3.1.
b. Totals might differ from sums of values due to rounding.
c. For this EIS, each combination of a shipping cask and railcar is assumed to be a single shipment.
d. SNF = spent nuclear fuel.
e. HLW = high-level radioactive waste.
f. GTCC = Greater-Than-Class-C.
g. SPAR = Special-Performance-Assessment-Required.

cask), various cask designs, and the transportation mode mix (mostly legal-weight truck or mostly rail). Appendix J contains additional details on Inventory Module 1 and 2 transportation requirements.

The following are the major differences between the repository facilities and operations for Inventory Modules 1 and 2 and those for the Proposed Action, which are described in Chapter 2:

- The longer time required to receive, package, and emplace the additional spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste, and to close the repository, for Inventory Module 1 or 2 versus that for the Proposed Action. The periods for the various project phases for Inventory Modules 1 and 2 would be the same.

- The need for more subsurface area to emplace about 17,000 to 26,000 waste packages for the Inventory Modules in comparison to about 11,000 to 17,000 waste packages for the Proposed Action.

Table 8-3 lists the differences in the expected time sequence for the repository construction, operation and monitoring, and closure phases for the Proposed Action and the Inventory Modules. DOE expects the construction phase to last for 5 years. Following this phase, repository development is projected to last for 22 years and emplacement for 24 years for the Proposed Action. During the operation and monitoring phase, development and emplacement is expected to last for 36 and 38 years, respectively, for Module 1 or Module 2. Monitoring activities during this phase would occur concurrently and then would extend beyond the emplacement period for up to 300 years. DOE expects the closure phase to last between 10 and 17 years for the Proposed Action and between 12 and 23 years for the Inventory Modules.

Table 8-3. Expected time sequence (years) of Yucca Mountain Repository phases for the Proposed Action and Inventory Module 1 or 2.

Inventory	Construction phase	Operation and monitoring phase: Development	Operation and monitoring phase: Emplacement[a]	Operation and monitoring phase: Monitoring	Closure phase
Proposed Action	5	22	24 - 50	76 - 300	10 - 17
Module 1 or 2	5	36	38 - 51	62 - 300	12 - 23

a. Range results from consideration of various operating modes with and without aging.

The amount of land required for surface facilities would increase only slightly for Inventory Module 1 or 2 from that for the Proposed Action (see Table 8-4). The design and operation of the repository surface facilities for Inventory Modules 1 and 2, including a Cask Maintenance Facility if it was at the Yucca Mountain site, would not differ much from those of the Proposed Action. The rate of material receipt,

Table 8-4. Amount of land (in square kilometers) newly disturbed at the proposed Yucca Mountain Repository for the Proposed Action and Inventory Module 1 or 2.[a,b,c]

Area	Proposed Action		Module 1 or 2	
	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
North Portal Operations Area	0.62	0.62	0.62	0.62
South Portal Development Area	0.15	0.15	0.15	0.15
Ventilation Shaft Operations Areas and access roads	0.83 (7 shafts)	1.04 - 1.42 (10 - 17 shafts)	1.13 (11 shafts)	1.38 - 1.89 (16 - 25 shafts)
Excavated rock storage area	0.87	0.87 - 1.51	1.40	1.40 - 2.02
Landfill	0.04	0.04 - 0.06	0.04	0.04 - 0.06
Solar power generating facility	0.22	0.22	0.22	0.22
Concrete batch plant	0.06	0.06	0.06	0.06
Surface aging facility	0	0 - 0.47	0	0 - 0.47
Totals	***2.8***	***3.0 - 4.5***	***3.6***	***3.9 - 5.5***

a. Source: DIRS 152010-CRWMS M&O (2000, Table 6-2, p. 52); DIRS 150941-CRWMS M&O (2000, p. 4-9 and Figure 6-1, p. 6-27); DIRS 155515-Williams (2001, 2.1-m Spacing Option: p. 27 and 29; 6.4-m Spacing Option: p. 24); DIRS 155516-Williams (2001, p. 3); DIRS 153882-Griffith (2001, p. 8).

b. To convert square kilometers to acres, multiply by 247.1.

c. Totals might differ from sums of values due to rounding.

packaging, and emplacement would be approximately the same and would require an extra 14 years beyond the 24-year emplacement period for the Proposed Action. There would be no difference in the duration of the emplacement period between Inventory Modules 1 and 2 because the surface and subsurface facilities could accommodate the small number of additional shipments and waste packages for Module 2.

The repository subsurface facilities for Inventory Module 1 or 2 would require about 60 percent more subsurface excavation than the Proposed Action. About 7.2 square kilometers (1,790 acres) would be required for the higher-temperature repository operating mode for Module 1 or 2, and from 10 to 15.4 square kilometers (2,480 to 3,810 acres) for the lower-temperature mode for Module 1 or 2. This compares to about 4.6 square kilometers (1,150 acres) and from 6.5 to 10.4 square kilometers (1,600 to 2,570 acres) for the higher- and lower-temperature modes, respectively, for the Proposed Action. Additional subsurface area would be needed if maximum spacing was used to achieve the lower-temperature mode. DOE would characterize this additional subsurface area, which would be adjacent to the blocks identified for the Proposed Action, more fully before its use. The subsurface facilities would not differ between Inventory Modules 1 and 2 for the lower-temperature operating mode with maximum-spacing because DOE would place the additional waste packages for Greater-Than-Class C and Special-Performance-Assessment-Required wastes between commercial spent nuclear fuel waste packages. However, total drift length would have to be increased by an estimated 3.7 to 4.9 kilometers (2.3 to 3.0 miles) for the other methods to achieve the lower-temperature operating mode when going from Inventory Module 1 to Module 2. There would be no difference in emplacement operating for Inventory Module 1 or 2 from those described for the Proposed Action in Chapter 2 unless DOE used the lower-temperature mode with surface aging. Because of the extra time involved in receiving and emplacing the Module 1 or 2 waste, there would be no delay in the process with the aging option before movement of the aged waste to the subsurface could begin, and DOE could move it at a faster rate. Monitoring and maintenance activities for Inventory Module 1 or 2 would be comparable to those for the Proposed Action with the exception of their duration in some cases.

Because there would be an increase in the number of waste packages and the increased length of the drifts that would be necessary for Inventory Module 1 or 2, the duration of the closure phase would be longer for Module 1 or 2 (12 to 23 years) compared to 10 to 17 years for the Proposed Action (see Table 8-3).

Inventory Module 1 or 2 closure phase activities would not otherwise differ from those described in Chapter 2 for the Proposed Action.

As discussed in the introduction to this chapter, the Department is not proposing at this time to emplace the additional materials from the Inventory Modules in the repository. If a future proposal was made to emplace these materials, the Department would ensure that appropriate National Environmental Policy Act reviews were performed.

8.1.2.2 Federal Actions

The following paragraphs describe reasonably foreseeable future actions of Federal agencies that could result in cumulative impacts in addition to those from Inventory Module 1 or 2.

Nellis Air Force Range

The Nellis Air Force Range (also referred to as the Nevada Test and Training Range) in south-central Nevada (see Figure 8-2) is a national test and training facility for military equipment and personnel. The *Renewal of the Nellis Air Force Range Land Withdrawal: Legislative Environmental Impact Statement* (DIRS 103472-USAF 1999, all) addresses the potential environmental consequences of the Air Force proposal to continue the Nellis Air Force Range land withdrawal for military use. As part of the actions analyzed in the Legislative EIS, the Air Force would renew its land withdrawal of almost 3 million acres and transfer responsibility to DOE for approximately 127,620 acres of land generally described as Pahute Mesa. Figures 8-2 and 8-3 show Pahute Mesa as part of the Nevada Test Site. The President signed S.1059 in October 1999, making it Public Law 106-65 and authorizing the renewed withdrawals and transfers described in the Legislative EIS.

The Air Force also issued the *Final Environmental Impact Statement F-22 Aircraft Force Development Evaluation and Weapons School Beddown at Nellis Air Force Base* in 1999 (DIRS 155928-Estrada 2001, all) to evaluate the potential impacts of locating F-22 aircraft at the Nellis Air Force Range. The action would entail the construction of some new facilities and other modifications to support the aircraft. The Record of Decision (DIRS 155918-Keck 1999, all) shows that the action "would result in either negligible effects or would not change current environmental conditions at Nellis AFB" for the major discipline areas. Therefore, DOE has not quantified potential cumulative impacts from this action. The descriptions of the affected environment in Chapter 3 and the potential impacts of the Proposed Action in Chapters 4, 5, and 6 include the effects of present activities at the Nellis Air Force Range.

Nevada Test Site

Several actions at the Nevada Test Site would pose a cumulative impact. Figure 8-3 shows a map of the Nevada Test Site to assist in identifying the location of these actions.

The *Final Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DIRS 101811-DOE 1996, all) examines current and future DOE activities in southern Nevada at the Nevada Test Site, Tonopah Test Range, and sites the Department formerly operated in Nevada. The first Record of Decision for that EIS (61 *FR* 65551, December 13, 1996) states that DOE would implement a combination of three alternatives: Expanded Use, No Action (continue operations at current levels) regarding mixed and low-level radioactive waste management, and Alternate Use of Withdrawn Lands regarding public education. On February 18, 2000, the Department issued an Amendment of the Record of Decision (65 *FR* 10061, February 26, 2000). In this Amendment, DOE decided, based on its National Environmental Policy Act reviews for the Nevada Test Site and for the Complex-wide waste management program described in the Programmatic Waste Management EIS (DIRS 101816-DOE 1997, all), to implement the Expanded Use Alternative for waste management activities at the Test Site, including mixed and low-level radioactive waste.

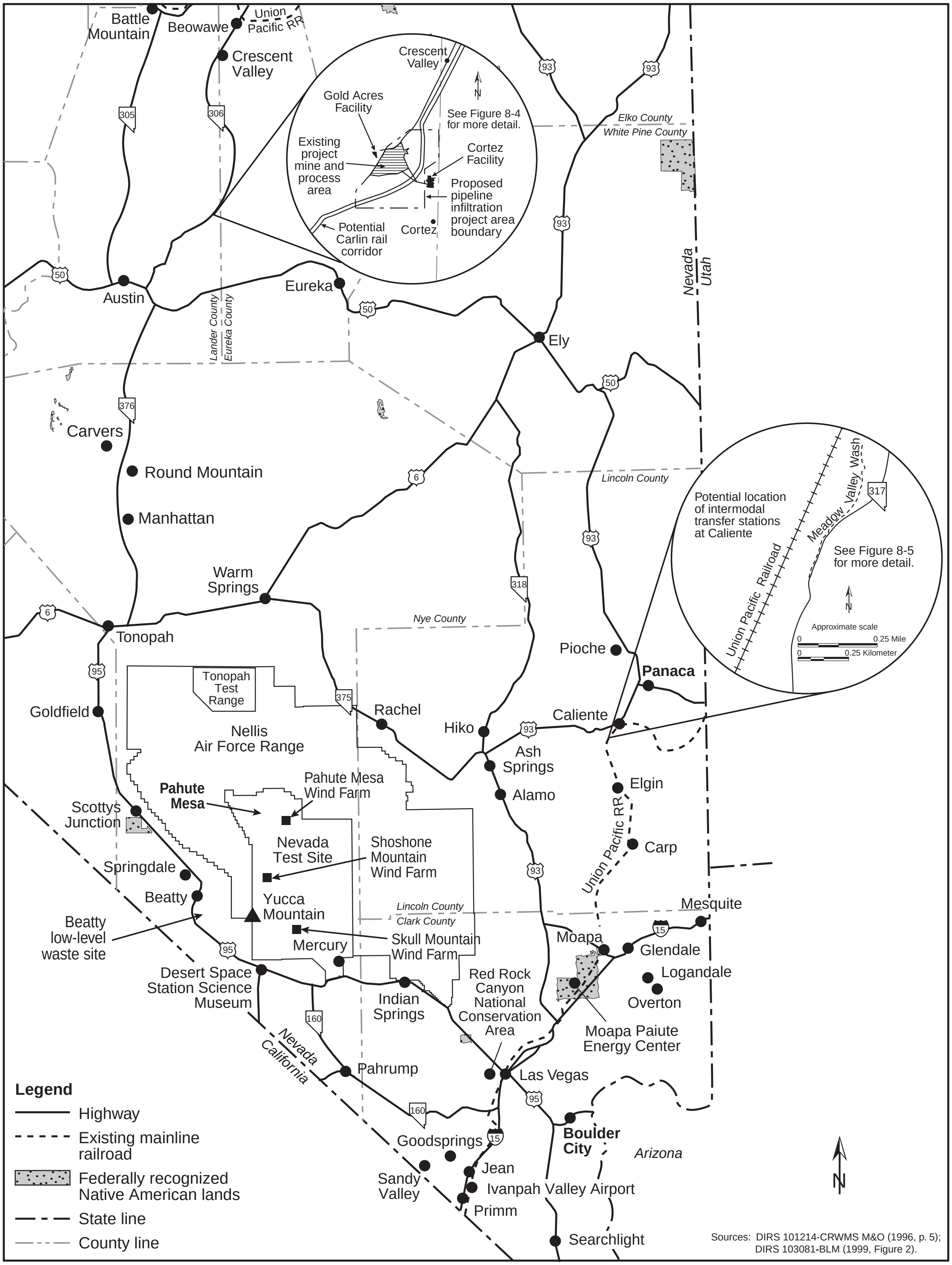

Figure 8-2. Locations of past, present, and reasonably forseeable future actions considered in the cumulative impact analysis.

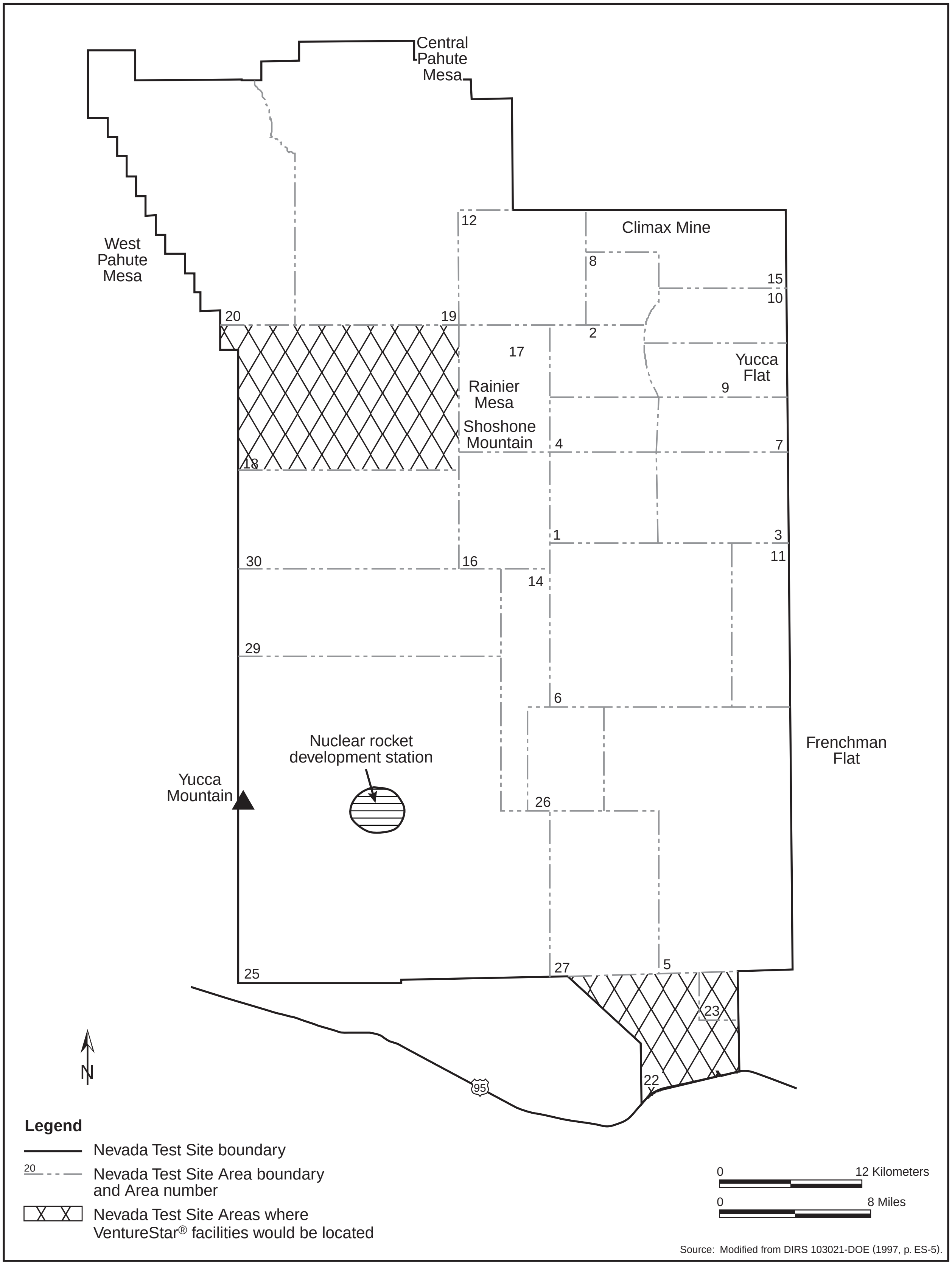

Figure 8-3. Potential locations of proposed cumulative activity associated with VentureStar®/Kistler at the Nevada Test Site.

The Expanded Use Alternative incorporates all the activities and operations from ongoing Nevada Test Site programs and increases some of those programs. Activities of the Office of Defense Programs would expand at both the Nevada Test Site and the Tonopah Test Range, primarily in the areas of stockpile stewardship and management, materials disposition, and nuclear emergency response. As part of the Stockpile Stewardship and Management Program, there are continuing *subcritical* weapons test activities to study aging of weapons components and their reliability after aging. Waste management activities would continue at current levels pending decisions by DOE based on the *Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DIRS 101816-DOE 1997, all). Based on the preferred alternative in the programmatic EIS, this cumulative impact analysis included the additional low-level and mixed waste that could come to the Nevada Test Site. The Environmental Restoration Program would continue, potentially at an accelerated rate, at the Nevada Test Site and all offsite locations. Under the Work for Others Program, military use of the airspace over the Nevada Test Site and the Tonopah Test Range would increase, as would the use of certain lands on the Nevada Test Site by the military for training, research, and development. Public education activities would include the possible construction of a museum that highlights Nevada Test Site testing activities. The Nevada Test Site Development Corporation is considering the VentureStar® program initiative from the Lockheed Martin Corporation for a launch/recovery system that would link with the Kistler Aerospace Satellite launch and recovery project. The VentureStar® program would require two spaceports, a manufacturing and assembly facility, and a payload processing and administrative complex. These activities could occur in Areas 18, 22, and 23, respectively (Figure 8-3). However, the Kistler aerospace activity is currently on hold (DIRS 152582-Davis 2000, all), and there is not enough information at this time to perform a cumulative impacts analysis for this project.

An analysis of the environmental impacts presented in the Nevada Test Site EIS (DIRS 101811-DOE 1996, all) (including impacts from weapons testing and the VentureStar®/Kistler project) identified the following resources for which impacts could overlap in relation to geography and timing with impacts from the proposed repository: air quality, groundwater, socioeconomics, public health and safety, and transportation. The effects on the Yucca Mountain Repository if a decision were made in the future to resume nuclear weapons testing or from a possible vehicle launch or recovery accident at the proposed VentureStar®/Kistler project are considered in the accident analysis of potential external events in Appendix H.

As discussed above in the section on the Nellis Air Force Range, part of the land previously assigned to the Range, specifically the parcel known as Pahute Mesa, has been transferred to the Nevada Test Site. The use of the land has not changed; this was a transfer of jurisdiction to match actual use with ownership.

A moratorium on the explosive testing of nuclear weapons began in October 1992. As discussed in the Nevada Test Site EIS, however, other testing continues at the Test Site, including dynamic, hydrodynamic, and explosive tests (DIRS 101811-DOE 1996, all). These tests are necessary for the continued assurance of the Nation's nuclear arsenal but do not result in nuclear explosions like those that were common during the Cold War. Therefore, environmental contamination from nuclear weapons testing is largely due to past testing and not to current activities at the Test Site. Although there are potential past and present impacts of the explosive testing of nuclear weapons, the long-lived radionuclides that have been deposited far underground could pose future impacts that are evaluated in Section 8.3. As shown in that section, DOE has made conservative assumptions to ensure the identification of any potential cumulative impacts between the Nevada Test Site and the proposed repository.

In March 2000, DOE published the *Nevada Test Site Development Corporation's Desert Rock Sky Park at the Nevada Test Site Environmental Assessment* (DIRS 155529-DOE 2000, all) and the associated

Finding of No Significant Impact. This environmental assessment evaluated the potential impacts of issuing a general use permit to the Nevada Test Site Development Corporation to develop, operate, and maintain a commercial/industrial park at the Test Site. The project would permit development of approximately 2 square kilometers (510 acres) of land already designated as a "private/commercial development zone."

In March 2001, DOE published the *Preapproval Draft Environmental Assessment for a Proposed Alternative Energy Generation Facility at the Nevada Test Site* (DIRS 154545-DOE 2001, all). The NTS Development Corporation (NTSDC) and the M&N Wind Power Inc. and Siemens (MNS) have requested authorization (under an easement between DOE and NTSDC and a subeasement between NTSDC and MNS) for the installation of 260 and 436 megawatts of a commercial wind-turbine-generated power system using as many as 545 wind turbine generators on three areas of the Nevada Test Site. The development of this system would allow for land use diversification of the Test Site by including nondefense and private use. The areas consist of the Shoshone Mountain Area, the Pahute Mesa, and Skull Mountain. DOE used these areas comprising 4.9 square kilometers (1,200 acres) for nuclear and conventional explosive testing facilities. The wind generators would be constructed on the ridges in these areas to maximize the effects of wind currents. They would be constructed in three phases and would not conflict with continued Nevada Test Site operations in the valley areas. On July 25, 2001, DOE announced its intention to prepare an EIS based on its analysis contained in the previous environmental assessment. This EIS would consider alternative locations and examine the impacts of the No-Action Alternative.

DOE Waste Management Activities

The Waste Management Programmatic EIS (DIRS 101816-DOE 1997, all) evaluates the environmental impacts of managing five types of radioactive and hazardous wastes generated by past and future nuclear defense and research activities at a variety of DOE sites in the United States. The five waste types are low-level radioactive waste, mixed low-level waste (referred to in this EIS as simply mixed waste), transuranic waste, high-level radioactive waste, and hazardous waste. The Waste Management Programmatic EIS provides information to assist DOE with decisions on the management of, and facilities for, the treatment, storage, and disposal of these radioactive, hazardous, and mixed wastes.

DOE has issued six Records of Decision or revisions to Records of Decision on the Programmatic Waste Management EIS (DIRS 101816-DOE 1997, all). The discussion of these decisions is presented in this section; however, the impacts of actions from these decisions would be related primarily to transportation of materials; these impacts are part of the analysis in Section 8.4. The first Record of Decision (63 *FR* 3629, January 23, 1998) announced the Department's decision to treat and store transuranic waste at each DOE facility except Sandia National Laboratory, which would transfer its transuranic waste to Los Alamos National Laboratory for preparation and storage. This waste would ultimately be disposed of in the Waste Isolation Pilot Plant in Carlsbad, New Mexico.

The fourth Record of Decision announced the Department's decision to make the Nevada Test Site and the Hanford Site available to all DOE sites for disposal of low-level waste and mixed low-level waste. This decision was accompanied by an amendment to the Record of Decision for the Nevada Test Site EIS (65 *FR* 10061, February 25, 2000) to implement the Expanded Use Alternative from that EIS.

On December 29, 2000, the Department announced a revision (65 *FR* 82985) to its decision regarding transuranic waste. Under this decision, the Department would establish at the Waste Isolation Pilot Plant the capability to prepare transuranic waste for disposal. In addition, the above-ground capacity at the Waste Isolation Pilot Plant would be increased by 25 percent.

On July 25, 2001, the Department issued (66 *FR* 38646) a further revision to its previous decision by announcing its decision to transfer about 300 cubic meters of transuranic waste from the Mound facility in Miamisburg, Ohio, to the Savannah River Site for storage, characterization, and repackaging prior to sending it to the Waste Isolation Pilot Plant.

The *Waste Isolation Pilot Plant Disposal Phase Final Supplemental Environmental Impact Statement* (DIRS 101814-DOE 1997, Chapter 5) identifies potential cumulative transportation impacts from the shipment of transuranic wastes from DOE sites across the United States, including the Nevada Test Site, to the Waste Isolation Pilot Plant in southeastern New Mexico for disposal.

Low-Level Waste Intermodal Transfer Station

DOE prepared a draft environmental assessment (DIRS 103225-DOE 1998, all) on a proposed action to encourage low-level radioactive waste generators and their contractors to use transportation alternatives that would minimize radiological risk, enhance safety, and reduce the cost of waste shipments to the Nevada Test Site. However, DOE determined that there was no decision for it to make relative to transportation of low-level radioactive waste that would require a National Environmental Policy Act analysis, and therefore no longer plans to issue a National Environmental Policy Act document. DOE has published a technical report that provides its low-level radioactive waste generators with a comparative risk analysis of alternative highway routes and intermodal transportation facilities (DIRS 155779-DOE 1999, all).

Road improvements to accommodate legal-weight trucks and the construction of a rail siding or spur on a 0.02-square-kilometer (5-acre) site 1.2 kilometers (0.75 mile) south of Caliente would be needed for the low-level radioactive waste intermodal transfer station. Lifting equipment (crane or forklift) would transfer containers of low-level radioactive waste from railcars to trucks for transport to the Nevada Test Site. Based on a 10-year average estimate of low-level waste volumes and shipments for the expanded use alternative from the Nevada Test Site EIS (DIRS 101811-DOE 1996, pp. 5-110 to 5-112), DOE expects the traffic through the intermodal transfer station to be less than 3 trains per day and about 14 trucks per day (7 outbound from the station and 7 returning from the Nevada Test Site). Intermodal transfer operations would occur only during daytime working hours, with containers dropped off during the night transported to the Nevada Test Site the following morning. A staff of three would be adequate to conduct operations at the station. Trucks would be inspected and decontaminated, as necessary, at the Nevada Test Site before returning to the station (DIRS 103225-DOE 1998, pp. 2-1 to 2-10 unless otherwise noted).

A high-end estimate for the planned trucking operation to support the low-level radioactive waste intermodal transfer station indicates a terminal on about 0.04 to 0.06 square kilometer (10 to 15 acres), a maintenance building 21 by 23 meters (70 by 75 feet), 9 tractors and 27 trailers, and 11 employees. One proposed location would be south and just outside of Caliente. Trucks would not pass through the Town of Caliente to reach the intermodal transfer station site (DIRS 103225-DOE 1998, p. 5-4).

The projections of low-level radioactive waste shipments from current DOE-approved generators to the Nevada Test Site do not extend to 2010 when shipments of spent nuclear fuel and high-level radioactive waste would begin to the proposed Yucca Mountain Repository. However, because it is reasonable to assume that low-level radioactive waste shipments to the Nevada Test Site could continue and occur coincidentally with shipments to the Yucca Mountain Repository, Section 8.4 analyzes the potential for cumulative impacts from the construction and operation of these two intermodal transfer stations as well as a privately owned intermodal transfer station described in the following section.

Timbisha Shoshone Reservation

The Secretary of the Interior issued a draft report to Congress (DIRS 103470-Timbisha Shoshone and DOI 1999, all) describing a plan to establish a discontiguous reservation for people of the Timbisha Shoshone Tribe in portions of the Mojave Desert in eastern California and southwestern Nevada. On

November 1, 2000, the President signed Bill S.2102 (Public Law 106-423) to provide a permanent land base for the Timbisha Shoshone Tribe within its ancestral homeland.

The National Park Service of the U.S. Department of the Interior prepared a Legislative EIS (DIRS 154121-DOI 2000, all), which describes the environmental impacts of this action. The EIS analyzes the potential transfer of almost 32 square kilometers (7,800 acres) in five noncontiguous parcels in portions of the Mojave Desert in eastern California and southwestern Nevada, as follows:

- Approximately 1.3 square kilometers (314 acres) in Furnace Creek, Death Valley National Park, California
- Approximately 4 square kilometers (1,000 acres) in Death Valley Junction, California
- Approximately 11 square kilometers (2,800 acres) in Scottys Junction, Nevada
- Approximately 2.6 square kilometers (640 acres) in Centennial, California
- Approximately 12 square kilometers (3,000 acres) in Lida, Nevada

Of these five parcels, the first three are in whole or in part within the 80-kilometer (50-mile) radius of the proposed repository. In addition to these five parcels, the Law authorizes the Secretary of the Interior to purchase two additional parcels of land with water rights as follows:

- Approximately 0.49 square kilometer (120 acres) at the Indian Rancheria Site, California
- Approximately 9.5 square kilometers (2,340 acres) at Lida Ranch, Nevada

In addition, Public Law 106-423 prescribes Federal water rights for these parcels of land and describes partnerships between the National Park Service and the Timbisha Shoshone Tribe that will provide economic and cultural opportunities for the Tribe while preserving the resources in the area. As described in the Legislative EIS (DIRS 154121-DOI 2000, all), activities on the parcels of land would not differ greatly from their historic uses. Modern housing with the associated infrastructure could be constructed at the Furnace Creek site, but would be limited by law to conserve and protect resources. Commercial development is permitted at several of the sites, but would have to be consistent with existing designations and uses of the land. The future development could cause potential transportation impacts, but the lack of information on specific plans precludes a detailed analysis at this time.

Because of the proximity of some of the parcels to the proposed repository and to some of the transportation corridors, there are potential cumulative impacts between their use and the proposed repository with regard to land use, regional water use, and transportation impacts. Therefore, DOE considered this action in its analysis of cumulative impacts in this chapter. As discussed in Chapter 6, the parcel near Scottys Junction (shown in Figure 8-1), if inhabited, could be affected if a rail corridor was used in the future.

8.1.2.3 Non-Federal and Private Actions

The following paragraphs describe reasonably foreseeable future actions of non-Federal and private agencies or individuals that could result in cumulative impacts. This EIS considers the Cortez Pipeline Gold Deposit projects described below to be private actions even though they require the approval of the Bureau of Land Management.

Cortez Pipeline Gold Deposit Projects

The Cortez Gold Mine Pipeline Project is near the potential branch rail line in the Carlin Corridor in Nevada (see Chapter 6, Section 6.3.2.2.2). Cortez Gold Mine, Inc., operates the Pipeline Project mine and processing facility; the environmental impacts of the existing mining operation are discussed in the *Cortez Pipeline Gold Deposit: Final Environmental Impact Statement* (DIRS 103078-BLM 1996, all). The Pipeline Infiltration Project (which was approved in March 1999) would expand the Pipeline Project area to add more land for the construction and operation of infiltration ponds to support the existing mine (DIRS 103081-BLM 1999, all). The Bureau of Land Management published the *South Pipeline Project Final Environmental Impact Statement* (DIRS 155530-BLM 2000, all) in which the proposed action was to "develop the South Pipeline ore deposit and construct associated facilities to continue to extract gold from the mined ore within the existing Project Area." Based on an analysis of the general area potentially affected by the Cortez Gold Mine Project, there could be cumulative land-use and ownership impacts with the proposed Carlin rail corridor (see Figure 8-2). The Bureau issued the Record of Decision for the EIS on June 27, 2000 (DIRS 155095-BLM 2000, all). On July 31, 2000, the Western Mining Action Project (representing Great Basin Mine Watch, Western Shoshone Defense Project, and Mineral Policy Center) filed an Appeal and Request for Stay (DIRS 155531-BLM 2001, all); however, the stay request was denied in January 2001.

Apex Bulk Commodities Intermodal Transfer Station

Apex Bulk Commodities is negotiating with BHP Copper of Ely, Nevada, to build an intermodal transfer station at Caliente near the potential intermodal transfer station site for shipping spent nuclear fuel and high-level radioactive waste to the proposed Yucca Mountain Repository. Apex anticipates one diesel truck per hour carrying 40 tons of copper concentrate, 24 hours per day, for 15 years. An improved access road and about 4,200 meters (14,000 feet) of new rail would be constructed. The transfer facility would be housed in a building 90 by 30 meters (300 by 100 feet) designed to retain dust, water, and spills generated during the transfer process. Air emission particulates would be collected in two baghouses. Apex would also need a truck maintenance facility, which would be in a building 30 by 18 meters (100 by 60 feet). An above-ground storage tank for about 45,000 liters (12,000 gallons) of diesel fuel is also planned. Apex estimates 25 new jobs for Caliente and an annual payroll of $800,000 (DIRS 103225-DOE 1998, p. 5-5).

Although a start date for Apex copper concentration intermodal transfer station and truck transportation operations is unknown, Section 8.4 analyzes the potential for cumulative impacts from the construction and operation of that station, assuming these activities would coincide with impacts from the Nevada Test Site low-level radioactive waste intermodal transfer station and the intermodal transfer station for shipments to the proposed Yucca Mountain Repository.

Shared Use of a DOE Branch Rail Line

If DOE built a branch rail line to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository, it could share the use of this line with others. A branch rail line in the Carlin corridor could provide transportation service options for mine operators in the central mountain valleys of Nevada and could provide freight service options for southwestern Nevada communities such as Tonopah, Beatty, Goldfield, and Pahrump. A branch rail line in the Caliente corridor could serve those communities plus Warm Springs, along with mine operators in the interior of Nevada. A branch rail line in the Valley Modified or Jean corridors would provide freight service access to farms, industries, and businesses in the Amargosa Valley and Pahrump communities. A Valley Modified branch line would also provide rail service to the Indian Springs community. Any of the potential branch rail lines to the Yucca Mountain site (see Chapter 6, Figure 6-14) would provide rail access to the Nevada Test Site. The shared use of a branch rail line would have positive economic benefits, but could produce cumulative impacts due to increased operations and traffic.

Private Fuel Storage at Skull Valley

In June 2000, the Nuclear Regulatory Commission published the *Draft Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (DIRS 152001-NRC 2000, all). That EIS evaluates the environmental impacts of constructing and operating a facility for the interim storage of commercial spent nuclear fuel.

The storage site would be on the reservation of the Skull Valley Band of Goshute Indians in Skull Valley in Tooele County, Utah. The facility would occupy approximately 3.3 square kilometers (820 acres) and would involve construction of a 52-kilometer (32-mile) rail line on public land administered by the Bureau of Land Management from Skunk Ridge (near Low, Utah) to the reservation.

The facility would be constructed and operated by Private Fuel Storage, LLC, a limited liability company comprised of eight U.S. power utilities.

The storage site would be designed to store up to 40,000 metric tons of heavy metal (MTHM) of commercial spent nuclear fuel, which is sufficient to store all the spent nuclear fuel from the Private Fuel Storage member utilities as well as additional fuel from non-member utilities. The fuel would be stored in above-ground concrete vault structures that would provide structural integrity and radiation shielding. The proposed facility would be licensed by the Nuclear Regulatory Commission to operate for as long as 20 years, at which time the Commission could renew the license.

The facility would be used as an interim storage facility until a geologic repository was available for disposal of the spent nuclear fuel. Therefore, the actions considered in the Nuclear Regulatory Commission EIS could have cumulative impacts with those contemplated in the Yucca Mountain EIS by affecting the transportation routes through which material would arrive at the proposed repository. However, because of the distance of the storage facility from the Yucca Mountain site, DOE does not expect cumulative impacts between the proposed operation of the facility and the Proposed Action for this EIS.

Section 8.4 discusses estimated impacts from transportation of material to the Private Fuel Storage facility.

Owl Creek Energy Project

The Owl Creek Energy Project (DIRS 155595-Stuart and Anderson 1999, all) is a potential interim storage project for commercial spent nuclear fuel that would be developed in the State of Wyoming. The location for the project is near the Town of Shoshoni, Wyoming, and consists of about 11 square kilometers (2,700 acres) of privately owned land with access to rail and nearby roads. A private company is pursuing the project, which would be temporary, with a projected life of 40 years.

The Owl Creek Energy Project would involve the storage of spent nuclear fuel using dry storage techniques in specially designed facilities. However, the project is still in its infancy; no license application has been submitted to the Nuclear Regulatory Commission. Further, the potential impacts of the facility are unknown at present. Therefore, DOE has not attempted to quantify potential impacts at this time, but believes it would be unlikely that the operational impacts would be markedly different from those expected for the Private Fuel Storage Facility in Tooele County, Utah (described above).

Moapa Paiute Energy Center

In March 2001, the Bureau of Indian Affairs issued the *Moapa Paiute Energy Center Draft Environmental Impact Statement* (DIRS 155979-PBS&J 2001, all). Calpine Corporation proposes to construct the Moapa Paiute Energy Center on 0.26 square kilometer (65 acres) of land leased from the Moapa River Paiute Reservation approximately 12 kilometers (45 miles) northeast of Las Vegas. The plant would consist of a nominal 760-megawatt baseload natural-gas-fired, combined-cycle power unit with peak capacity to approximately 1,100 megawatts. The land disturbance would consist of as much as 0.88 square kilometer (218 acres) of reservation land and as much as 0.33 square kilometer (82 acres) of off-reservation lands. Transmission lines would follow an existing Bureau of Land Management utility corridor that passes through the reservation, requiring no change in land use. The lines would pass approximately 19 kilometers (12 miles) to the southwest to the existing Nevada Power Company Harry Allen Substation. The natural gas supply system to the facility would consist of approximately 1,220 meters (4,000 feet) of pipeline and a pumping station. The natural gas line and the pump station would require approximately 0.004 square kilometer (5.5 acres). The Bureau of Land Management would be responsible for rights-of-way for construction, operation, and termination for the facilities in the utility right-of-way on the reservation.

Because the Energy Center would be some distance from the proposed repository, there is minimal potential for direct cumulative impacts with repository operation. Groundwater management practices would minimize depletion of groundwater resources. Air emissions would be minimized, and there would be essentially no potential for overlap of the plumes from the repository and the Energy Center.

Southern Nevada Public Land Management Act

The Southern Nevada Public Land Management Act (Public Law 105-263) authorizes the Bureau of Land Management to sell some public lands in the Las Vegas Valley to promote responsible and orderly development.

The law specifies that money generated by these land sales will remain in Nevada. This money will provide funding for a variety of land management activities emphasizing recreation sites, such as the following:

- Acquisition of environmentally sensitive land in Nevada, with priority given to lands in Clark County
- Capital improvements at the Lake Mead National Recreation Area, the Desert National Wildlife Refuge, the Red Rock Canyon National Conservation Area, and other areas administered by the Bureau of Land Management in Clark County, and the Spring Mountains National Recreation Area (subject to an annual limitation)
- Development of a multispecies habitat conservation plan in Clark County, Nevada
- Development of parks, trails, and natural areas in Clark County

The Act included approximately 110 square kilometers (27,000 acres) of land for sale (Public Law 105-263). As of April 2001, the Bureau of Land Management had conveyed about 17 square kilometers (4,200 acres) to private and commercial entities. In December 2000, the Bureau published its “Round 2 Preliminary Recommendation” in which it recommended the acquisition of more than 23 square kilometers (5,800 acres) of land throughout Nevada that is privately or commercially owned to be distributed among the Bureau, the National Park Service, and the Forest Service (DIRS 155597-BLM 2000, all).

This action has potential land use cumulative impacts because some of the parcels conveyed or acquired by the Bureau of Land Management could be either within the 80-kilometer (50-mile) radius of the proposed repository or near potential transportation corridors, although DOE cannot predict which parcels might be affected or the timing of such conveyances.

Ivanpah Valley Airport

On October 27, 2000, the President signed the Ivanpah Valley Airport Public Lands Transfer Act (Public Law 106-362) to transfer Federal lands in Ivanpah Valley, Nevada, to Clark County. The land to be transferred, which is part of the Mojave National Preserve, would be used for construction of a general aviation airport at Jean, Nevada.

The passage of the Ivanpah Valley Airport Public Lands Transfer Act does not automatically transfer the lands. Under provisions of the bill, the U.S. Departments of the Interior and Transportation must complete an environmental impact statement before an actual transfer. As described in Chapter 6, the initiation of the Stateline option of the Jean Corridor for a potential branch rail line encroaches upon the land to be transferred. Therefore, this EIS evaluates the potential for cumulative impacts due to the land transfer.

Desert Space Station Science Museum

The Nevada Science and Technology Center is proposing to construct an 8,800-square-meter (95,000-square-foot) museum on 1.8 square kilometers (450 acres) of land in Amargosa Valley at the intersection of U.S. Highway 95 and State Route 373 (DIRS 148148-Williams and Levy 1999, p. 1). The land would be transferred from the Bureau of Land Management to Nye County, which in turn would lease the land to the Nevada Science and Technology Center (DIRS 155478-Dorsey 2001, all). As shown in Figure 8-2, this parcel of land is near the Nevada Test Site and is, thus, within the region of influence for the proposed repository.

Because detailed quantitative impact information is not available, DOE has not included a detailed analysis of this action other than to report the potential land use implications in Section 8.2.1.

8.2 Cumulative Short-Term Impacts in the Proposed Yucca Mountain Repository Region

This section describes short-term cumulative impacts during the construction, operation and monitoring, and closure of the repository in the regions of influence for the resources the repository could affect. DOE has organized the analysis of cumulative impacts by resource area. As necessary, the discussion of each resource area includes cumulative impacts from Inventory Module 1 or 2; from other Federal, non-Federal, and private actions; and from the combination of Inventory Modules 1 and 2 and other Federal, non-Federal, and private actions. Table 8-5 summarizes these impacts. The impacts listed for the Proposed Action in Table 8-5 include the combined effects of the potential repository and transportation activities.

There would be essentially no difference in the design and operation of the repository for Inventory Modules 1 and 2. As described in Appendix A, the radioactive inventory for Greater-Than-Class-C waste and for Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. The subsurface emplacement of the material in Inventory Module 2, in comparison with the inventory for Module 1, would not greatly increase radiological impacts to workers or the public (DIRS 104523-CRWMS M&O 1999, p. 6-44). For the surface facilities, the number of workers and the radiological exposure levels would be the same for Inventory Modules 1 and 2 (DIRS 104508-CRWMS M&O 1999, Tables 6-1, 6-2, 6-4, and 6-5). Therefore, DOE did not perform separate analyses for Modules 1 and 2 to estimate the short-term impacts. This section identifies the short-term impacts as being for Modules 1 and 2, indicating that the impacts for the two modules would not differ greatly.

Ivanpah Valley Airport

On October 27, 2000, the President signed the Ivanpah Valley Airport Public Lands Transfer Act (Public Law 106-362) to transfer Federal lands in Ivanpah Valley, Nevada, to Clark County. The land to be transferred, which is part of the Mojave National Preserve, would be used for construction of a general aviation airport at Jean, Nevada.

The passage of the Ivanpah Valley Airport Public Lands Transfer Act does not automatically transfer the lands. Under provisions of the bill, the U.S. Departments of the Interior and Transportation must complete an environmental impact statement before an actual transfer. As described in Chapter 6, the initiation of the Stateline option of the Jean Corridor for a potential branch rail line encroaches upon the land to be transferred. Therefore, this EIS evaluates the potential for cumulative impacts due to the land transfer.

Desert Space Station Science Museum

The Nevada Science and Technology Center is proposing to construct an 8,800-square-meter (95,000-square-foot) museum on 1.8 square kilometers (450 acres) of land in Amargosa Valley at the intersection of U.S. Highway 95 and State Route 373 (DIRS 148148-Williams and Levy 1999, p. 1). The land would be transferred from the Bureau of Land Management to Nye County, which in turn would lease the land to the Nevada Science and Technology Center (DIRS 155478-Dorsey 2001, all). As shown in Figure 8-2, this parcel of land is near the Nevada Test Site and is, thus, within the region of influence for the proposed repository.

Because detailed quantitative impact information is not available, DOE has not included a detailed analysis of this action other than to report the potential land use implications in Section 8.2.1.

8.2 Cumulative Short-Term Impacts in the Proposed Yucca Mountain Repository Region

This section describes short-term cumulative impacts during the construction, operation and monitoring, and closure of the repository in the regions of influence for the resources the repository could affect. DOE has organized the analysis of cumulative impacts by resource area. As necessary, the discussion of each resource area includes cumulative impacts from Inventory Module 1 or 2; from other Federal, non-Federal, and private actions; and from the combination of Inventory Modules 1 and 2 and other Federal, non-Federal, and private actions. Table 8-5 summarizes these impacts. The impacts listed for the Proposed Action in Table 8-5 include the combined effects of the potential repository and transportation activities.

There would be essentially no difference in the design and operation of the repository for Inventory Modules 1 and 2. As described in Appendix A, the radioactive inventory for Greater-Than-Class-C waste and for Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. The subsurface emplacement of the material in Inventory Module 2, in comparison with the inventory for Module 1, would not greatly increase radiological impacts to workers or the public (DIRS 104523-CRWMS M&O 1999, p. 6-44). For the surface facilities, the number of workers and the radiological exposure levels would be the same for Inventory Modules 1 and 2 (DIRS 104508-CRWMS M&O 1999, Tables 6-1, 6-2, 6-4, and 6-5). Therefore, DOE did not perform separate analyses for Modules 1 and 2 to estimate the short-term impacts. This section identifies the short-term impacts as being for Modules 1 and 2, indicating that the impacts for the two modules would not differ greatly.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 1 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Land use and ownership	Withdraw about 600 square kilometers (150,000 acres) of land already under Federal control by DOE, U.S. Air Force, and Bureau of Land Management. Public access to about 200 square kilometers (50,000 acres) of BLM public lands would be terminated. About 6.0 square kilometers (1,500 acres) of withdrawn land would be disturbed for the repository under the Proposed Action. As much as 20 square kilometers (4,900 acres) of land would be disturbed along transportation routes in Nevada, a portion of which would be in the Yucca Mountain region and could include the need for rights-of-way agreements or withdrawals.	Land withdrawal impacts would be the same as those for the Proposed Action. As much as 1 square kilometer (250 acres) of additional land would be disturbed, for a total of as much as 7.0 square kilometers (1,730 acres). Land use and ownership impacts from transportation would be the same as for the Proposed Action.	In addition to impacts for the Proposed Action, under current and reasonably foreseeable actions, 10,000 acres of federal land would be transferred for Indian reservations; 65 acres of reservation land would be used for commercial purposes; in excess of 38,000 acres of Federal land would be used for private and commercial purposes. There is the potential for over 5,800 acres of privately owned land to be acquired by the Federal Government. An intermodal transfer station could be constructed for shipping low-level radioactive waste within the Yucca Mountain region.	Withdraw about 600 square kilometers (150,000 acres) of land already under Federal control by DOE, U.S. Air Force, and Bureau of Land Management. Public access to about 200 square kilometers (50,000 acres) of BLM public lands would be terminated. As much as 27 square kilometers (1,100 acres) of withdrawn land would be disturbed for the repository and along transportation route. In addition to impacts for the Proposed Action, under current and reasonably foreseeable actions, 10,000 acres of federal land would be transferred for Indian reservations; 65 acres of reservation land would be used for commercial purposes; in excess of 38,000 acres of Federal land would be used for private and commercial purposes. There is the potential for over 5,800 acres of privately owned land to be acquired by the Federal Government.
Air Quality				
Nonradiological	Criteria pollutant [nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter (PM_{10}, $PM_{2.5}$)] and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be less than 6 percent of applicable regulatory limits (see Tables 8-6, 8-7, and 8-8). Emissions associated with transportation in the proposed repository region would be low.	Criteria pollutant and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be less than 7 percent of applicable regulatory limits (see Tables 8-6, 8-7, and 8-8). Emissions associated with transportation in the proposed repository region would be low.	Nevada Test Site: Baseline monitoring shows that criteria pollutants at the Nevada Test Site and in the proposed repository region are well below National Ambient Air Quality Standards and would result in very small cumulative nonradiological air quality impacts. Emissions associated with the transportation of waste, people, and materials for Nevada Test Site activities in the repository region would be low.	Criteria pollutant and cristobalite concentrations calculated at the analyzed land withdrawal area boundary would be small fractions of applicable regulatory limits (generally less than 10 percent). Emissions associated with transportation in the repository region would be low.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 2 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Air Quality (continued)				
Radiological[b]	The maximally exposed individual in the public would receive an estimated annual radiation dose of 1.3 millirem or less (see Tables 8-10, 8-11, 8-12, and 8-13), primarily from naturally occurring radon.	The maximally exposed individual in the public would receive an estimated annual dose of 2.2 millirem or less, primarily from naturally occurring radon.	Nevada Test Site: Activity would continue to contribute extremely small increments to the risk to the general population and should not increase injury or mortality rates. As an example, the maximally exposed individual in the public would receive an estimated annual radiation dose of less than 0.15 millirem from past, present and reasonably foreseeable future activities.	The maximally exposed individual in the public would receive an annual radiation dose of 2.5 millirem or less, which is well below the 10 CFR 63.204 limit of 15 millirem from radioactive material releases from the repository and the Nevada Test Site.
Hydrology				
Surface water	Between 2.8 and 4.5 square kilometers (690 and 1,100 acres) of land would be newly disturbed and resulting impacts would likely be small and limited to the site. Impacts from construction and use of transportation capabilities (heavy-haul and rail) in the site vicinity and region would result in small impacts to surface water. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Additional transportation floodplain/wetlands assessments would be performed in the future as necessary.	Would be similar to impacts from the Proposed Action with an increase of as much as 1 square kilometer (250 acres) in new surface disturbance for a total of as much as 5.5 square kilometers (1,360 acres). Impacts from construction and use of transportation capabilities (heavy-haul and rail) would be small. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.	No other actions were identified with potential cumulative surface-water impacts within the region of influence of repository construction, operation and monitoring, and closure. Transportation impacts would be small.	As much as 5.5 square kilometers (1,360 acres) of land would be newly disturbed and resulting impacts would likely be minor and limited to the site. Impacts from construction and use of transportation capabilities (heavy-haul and rail) in the site vicinity and region would result in small impacts to surface water. Minor changes to runoff and infiltration rates. Floodplain/wetlands assessment concluded impacts would be small. Transportation floodplain/wetlands assessments would be performed in the future as necessary.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 3 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Hydrology (continued)				
Groundwater	Annual water demand would be between 230 and 290 acre-feet (during emplacement), and below the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet). Water use for the construction of a rail line could be as much as 710 acre-feet from multiple wells and hydrographic areas over 4 years.	Anticipated annual water demand (below Nevada State Engineer's ruling on perennial yield) could be slightly higher (ranging from 240 to 320 acre-feet) than that of the Proposed Action, and the highest demand, which would also occur when emplacement and development activities occurred together, would extend for an additional 14 years. Water use for transportation would be the same as that for the Proposed Action.	Nevada Test Site: Anticipated annual water demand from Nevada Test Site activities would be about 280 acre-feet, which is less than the estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet).	Combining the highest annual water demand of the repository of 320 acre-feet (during emplacement and development activities for the lower-temperature maximum spacing scenario with Modules 1 or 2) with annual water withdrawals from the Nevada Test Site of 280 acre-feet would result in a total of 600 acre-feet, which would slightly exceed the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet), but would not approach the highest estimate of perennial yield, which is 4,000 acre-feet. There is a potential for drawdown of the water level in nearby wells from water withdrawal. The combined peak annual water use of a repository under other operation options, even with Modules 1 or 2, with Nevada Test Site annual water use would result in a maximum peak cumulative use of about 560 acre-feet per year, which is below the lowest estimate of perennial yield of the western two-thirds of the Jackass Flats basin (580 acre-feet). In addition, up to 710 acre-feet of water over 2.5 years would be used to construct a rail line in Nevada.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 4 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Biological resources and soils	Between 2.8 and 4.5 square kilometers (690 to 1,100 acres) of soil, habitat, and vegetation would be newly disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise and loss of individuals would occur. Wetland assessment concluded impacts would be small. Impacts from transportation would include the loss of 0 (legal-weight truck) to 20 square kilometers (4,900 acres) (rail) of habitat in Nevada. Impacts to the desert tortoise probably would occur if a rail line were constructed. Additional wetlands assessments would be performed in the future as necessary.	Inclusive of the Proposed Action, a total of as much as 5.5 square kilometers (1,360 acres) of soil, habitat, and vegetation would be disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise would occur. Wetland assessment concluded impacts would be small. Impacts from transportation would be the same as those under the Proposed Action. Additional wetlands assessments would be performed in the future as necessary.	No other actions were identified with potential cumulative biological resource or soil impacts within the region of influence of repository construction, operation and monitoring, and closure.	As much as 5.5 square kilometers (1,360 acres) of soil, habitat, and vegetation would be newly disturbed, resulting in lost productivity and animal mortality and displacement. Adverse impacts to the desert tortoise and loss of individuals would occur. Impacts to potential jurisdictional wetlands would be very small and minimized. Impacts from transportation would include the loss of 0 (legal-weight truck) to 20 square kilometers (4,900 acres) (rail) of habitat in Nevada, a portion of which would be within the Yucca Mountain vicinity. Impacts to the desert tortoise and wetlands probably would occur if a rail line were constructed. Additional wetlands assessments would be performed in the future as necessary.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 5 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Cultural resources	Repository development would disturb about 2.8 to 4.5 square kilometers (690 to 1,100 acres). Direct and indirect impacts (damage to archaeological and historical sites or illicit collection of artifacts) would be mitigated per applicable regulations. In addition, as much as 20 square kilometers (4,900 acres) would be disturbed along transportation routes in Nevada. Native Americans view all impacts to be adverse and immune to mitigation.	Land disturbance for repository development would increase to a total of as much as 5.5 square kilometers (1,360 acres). Transportation impacts would be the same as those under the Proposed Action. Direct and indirect impacts and mitigations would be similar to the Proposed Action. Native Americans view all impacts to be adverse and immune to mitigation.	No other actions were identified with potential cumulative cultural resource impacts within the region of influence of repository construction, operation and monitoring, and closure. Native Americans view all impacts to be adverse and immune to mitigation.	Repository development would disturb as much as 5.5 square kilometers (1,360 acres). As much as 20 square kilometers (4,900 acres) would be disturbed if a rail line was constructed in Nevada. Direct and indirect impacts (damage to archaeological and historical sites or illicit collection of artifacts) would be mitigated per applicable regulations. Native Americans view all impacts to be adverse and immune to mitigation.
Socioeconomics	Estimated peak direct employment of 3,400 occurring in 2006 would result in less than a 1 percent increase in direct and indirect regional employment. Employment increases would range from less than 1 percent to approximately 5 percent (use of intermodal transfer station or rail line in Lincoln County, Nevada) of total employment by county.	Estimated peak direct employment would be the same as for the Proposed Action.	Nevada Test Site: Any employment increases would occur prior to construction of the repository and no cumulative impacts would be expected.	Estimated peak employment increase of about 3,400 occurring in 2006 would result in less than a 1-percent increase in direct and indirect regional employment (with as much as a 5-percent change in Lincoln County, Nevada if intermodal transfer station or rail line were located there).
Occupational and public health and safety[d]				
Nonradiological health impacts	2 to 3 fatalities[e] during construction, operation and monitoring, and closure. Exposures well below regulatory limits. Also, between 14 and 26 fatalities[e] from commuting, and transportation of material (repository and rail line construction material, as well as spent nuclear fuel and high-level radioactive waste).	4 or less fatalities[e] during construction, operation and monitoring, and closure. Exposures well below regulatory limits. Also, between 19 and 33 fatalities[e] from commuting, and transportation of material (repository and rail line construction material, as well as spent nuclear fuel and high-level radioactive waste).	No other actions were identified with potential cumulative industrial hazard impacts to repository workers.	23 to 37 fatalities[e] during construction, operation and monitoring, and closure (including transportation). Exposures well below regulatory limits.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 6 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Occupational and public health and safety (continued)[d]				
Radiological health impacts				
Workers	4 to 7 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure. Up to 3 to 12 latent cancer fatalities[e] to workers from mostly rail and mostly truck, respectively.	5 to 8 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure. Up to 7 to 24 latent cancer fatalities[e] to workers from mostly rail and mostly truck, respectively.	No other actions were identified with potential cumulative radiological health impacts to repository workers.	About 12 to 32 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure (including transportation).
Public	Estimated doses would result in less than 1 latent cancer fatality to the public from repository construction, operation and monitoring, and closure. Up to 1 to 3 latent cancer fatalities[e] would result from transport by mostly rail and mostly truck, respectively.	Estimated doses would result in less than one latent cancer fatality to the public from repository construction, operation and monitoring, and closure. Impacts from transportation would be almost twice those from the Proposed Action.	Nevada Test Site: Estimated doses and associated health effects from the Nevada Test Site would be less than one latent cancer fatality.	About 2 to 5 latent cancer fatalities[e] from repository construction, operation and monitoring, and closure (including transportation); and Nevada Test Site activities.
Accidents	No latent cancer fatalities would be likely from the maximum reasonably foreseeable repository accident scenarios. Between 1 and 5 latent cancer fatalities would result from a maximum reasonably foreseeable transportation accident scenario that has less than 3 chances in 10 million of occurring.	The accident risk (probability of occurrence times consequence) is essentially the same as that for the Proposed Action. Impacts of a maximum reasonably foreseeable transportation accident scenario would be the same as those for the Proposed Action.	No other actions were identified with potential cumulative accident risk impacts.	No latent cancer fatalities would be likely from the maximum reasonably foreseeable repository accident scenarios. Between 1 and 5 latent cancer fatalities would result from a maximum reasonably foreseeable transportation accident scenario that has less than 3 chances in 10 million of occurring.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 7 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Noise	Impacts from construction, operation and monitoring, and closure of a repository would result in low noise impacts. Noise levels would be transient, less than 90 dBA[c]. New intermittent noise source if a rail line was used in Nevada, including in the Yucca Mountain region.	Same as the Proposed Action.	Future development of the Timbisha Shoshone Homeland parcel near Scottys Junction could result in residents or businesses being exposed to up to 90 dB of noise from the transportation route.	Impacts from construction, operation and monitoring, and closure of a repository would result in low noise impacts. Noise levels would be transient, less than 90 dBA[c]. New intermittent noise source if a rail line was used in Nevada, including in the Yucca Mountain.
Aesthetics	Placement of exhaust stacks on top of Yucca Mountain could possibly impact visual resources, since stacks would be visible for some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Rail line construction would occur if rail was used in Nevada. Possible conflict with visual resource management goals for Jean rail corridor.	Same as the Proposed Action.	Disturbed areas are likely on former federal lands that are used for commercial and private purposes. Acquisition of private lands by the federal government could result in reduced aesthetics impacts and possible return of land to natural state.	Placement of exhaust stacks on top of Yucca Mountain could possibly impact visual resources, since stacks would be visible for some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Rail line construction would occur if rail was used in Nevada. Possible conflict with visual resource management goals for Jean rail corridor. Disturbed areas are likely on former federal lands that are used for commercial and private purposes. Acquisition of private lands by the federal government could result in reduced aesthetics impacts and possible return of land to natural state.
Utilities, energy, materials, and site services	Peak electric power demand would require an upgrade to the electrical transmission and distribution system. Adverse impacts on energy and material supplies or to site services would be unlikely, including materials needed for transportation capabilities in the Yucca Mountain vicinity.	Peak electric power demand would require upgrade to the electrical transmission and distribution system. Although requirements for electricity, fossil fuels, concrete, steel, and copper would increase, adverse impacts to energy and material supplies or to site services would be unlikely, including materials needed for transportation capabilities in the Yucca Mountain vicinity.	Construction of other energy supply facilities, such as the Moapa Paiute Energy Center or the Alternative Energy Facility at the Nevada Test Site could provide additional electrical capacity for the region.	Peak electric power demand would require upgrade to the electrical transmission and distribution system. (See Chapter 4, Section 4.1.11.) Adverse impacts on energy and material supplies or to site services would be unlikely, including materials needed for transportation capabilities in the Yucca Mountain vicinity.

Table 8-5. Summary of cumulative short-term impacts in the proposed Yucca Mountain Repository region (page 8 of 8).

Resource area	Proposed Action (repository and transportation)	Inventory Module 1 or 2[a]	Other Federal, non-Federal, and private actions	Total cumulative impacts
Waste management	Disposal of repository-generated low-level waste would require about 4 percent of the reserve capacity of the Nevada Test Site. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, existing landfills would need to be expanded.	Disposal of repository-generated low-level waste would require about 9 percent of the reserve capacity of the Nevada Test Site. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, the larger quantity of this waste would require even further landfill expansion at the Nevada Test Site.	Nevada Test Site: The total low-level radioactive waste disposal capacity of the Nevada Test Site is sufficient and would not be exceeded by the combined actions of repository development and selection of the Nevada Test Site as a regional disposal site for DOE-complex-wide low-level radioactive and mixed wastes.	The Nevada Test Site has sufficient capacity for low-level radioactive waste from all reasonably foreseeable future actions. If nonradioactive, nonhazardous solid waste would be disposed of at the Nevada Test Site, existing landfills would need to be expanded.
Environmental justice	No disproportionately high and adverse impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.	No disproportionately high and adverse impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.	No other actions were identified with potential cumulative impacts within the region of influence of repository construction, operation and monitoring, and closure that would create environmental justice concerns. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for repository or transportation activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that implementing the Proposed Action would continue restrictions on access to the proposed site.

a. As described in Section 8.1.2.1, there would be essentially no difference in the design and operation of the repository for Inventory Module 1 or 2. Therefore, the analysis considered cumulative impacts from Inventory Module 2 to be the same as those from Inventory Module 1.

b. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public.

c. dBA = A-weighted decibels, a common sound measurement. A-weighting accounts for the fact that the human ear responds more effectively to some pitches than to others. Higher pitches receive less weighting than lower ones.

d. Occupational and public health and safety impacts for the Proposed Action and Inventory Module 1 or 2 include both impacts from transportation activities in the repository region of influence as well as impacts estimated to occur nationally from transportation of spent nuclear fuel and high-level radioactive waste.

e. These ranges represent the maximum for each environmental resource area. Because the maximum could occur for different implementing alternatives in the various resource areas, simple addition of these summary level maximums could overstate the impacts due to mixing of incompatible alternatives.

DOE performed quantitative calculations for long-term impacts for both modules (see Section 8.3.1). The conclusion from these quantitative estimates was that the long-term impacts for Modules 1 and 2 would not differ greatly.

In estimating the potential impacts considered in this EIS, DOE consulted various documents, including resource plans, other National Environmental Policy Act documents, and technical documents. If appropriate, DOE has cited these documents in the discussion of each technical discipline.

Based on comments received during scoping and on the Draft EIS, DOE considered the Special Nevada Report from September 1991 (DIRS 153277-SAIC 1991, all) for inclusion as a source of technical information for the EIS. The Special Nevada Report, which was mandated by the Military Lands Withdrawal Act of 1986, contains a description of defense-related activities (as identified in 1991) along with estimates of potential impacts from those activities. However, the cumulative impacts analysis in this chapter considered the agencies that report represents—the Department of the Air Force, Department of the Navy, and Department of the Interior. Evaluations of the cumulative impacts of repository activities and other agency activities included review of a number of documents that are more current than the Special Nevada Report, including National Environmental Policy Act documents prepared by the Federal agencies listed throughout Section 8.1. Therefore, based on these more recent reports, DOE believes this report does not provide additional insight into projections of future impacts and, therefore, did not use it in its analysis of cumulative impacts.

8.2.1 LAND USE AND OWNERSHIP

The ownership, management, and use of the analyzed land withdrawal area described in Chapter 4, Section 4.1.1 for the Proposed Action would not change for Inventory Module 1 or 2. The amount of land required for surface facilities would increase somewhat for Module 1 or 2 because of the larger storage area for excavated rock and additional ventilation shafts for the larger required repository. This would have no substantial cumulative land-use or ownership impact.

To identify and quantify cumulative impacts for land use, DOE used a twofold approach. Actions that occurred within a 50-mile (80-kilometer) radius of the repository were reviewed for potential contributions to land use impacts. Second, actions that could affect transportation corridors were reviewed for their potential land use impacts. This second group of impacts is discussed in Section 8.4.2.1 (see Table 8-4).

Section 8.1 lists several actions that have the potential for land use impacts. DOE reviewed those actions to identify land areas that could be affected and has quantified, where possible, the amount of land that is subject to new uses. DOE identified how the land use would be converted (for example, undisturbed federal land to commercial use) and any restrictions that might affect the length of time the land would be used.

As discussed in Chapter 3, Section 3.1.1.1, the Federal Government manages approximately 240,000 square kilometers of land in Nevada, approximately 190,000 square kilometers of which are managed by BLM and available for public use. The land transfer/usage indicated in Table 8-6 represents approximately 340 square kilometers of additional land that is currently scheduled for removal from public use. In addition approximately 430 square kilometers would require removal from public use as the result of the potential development of a repository and transportation corridor. The total land removed from public use would represent less than 0.5 percent of BLM land and approximately 0.3 percent of the total Federal lands of Nevada. The largest change in land use is associated with the Southern Nevada Public Land Management Act. Although the Bureau of Land Management could convey as much as 110 square kilometers (27,000 acres) to private and commercial use, only about 17 square kilometers (4,200 acres) had been transferred as of April 30, 2001. As stipulated by the Act,

Table 8-6. Potential cumulative land use impacts for activities in or near the region of influence.[a]

Action	Land use conversion[b]	Ownership change	Land use restrictions
Moapa Paiute Energy Center[c]	Powerplant construction/ operation on 0.26 square kilometers of Reservation land.	Moapa Band of Paiute Indians to Calpine Corporation – powerplants footprint. Reservation to BLM for management of new natural gas pipeline	25-year lease with 20-year renewal
Ivanpah Cargo Airport[d]	Recreation and mining to airport and industrial development. Approximately 27 square kilometers, 8.1 square kilometers of which is for airport alone.	BLM to Clark County for public/private development	None
Timbisha Shoshone Reservation[e]	Grazing, recreation, mining, wildlife management to Tribal use (economic development, historic/cultural use, special use). Approximately 40 square kilometers.	NPS, BLM, and private lands to reservation/BIA	None
Cortez Mine[f]	Grazing, recreation, mining to mining 18 square kilometers.	BLM lease to Cortez Gold Mine	10 years
NTS Energy Generation Facility (Wind Farm)[g]	DOE land withdrawn for NTS to commercial use–4.9 square kilometers.	NTS subeasement to MNS through NTSDC	20 year generation period
Southern Nevada Public Land Management Act[h,i]	BLM general use to private/ commercial development and private/commercial land to public land. • Potential of 110 square kilometers to be transferred • 17 square kilometers conveyed as of April 30, 2001 • More than 23 square kilometers recommended by BLM to be acquired	• BLM to private/commercial • Private/commercial to BLM, NFS, NPS	None
Desert Space Station Science Museum[j]	BLM general use to commercial use (1.8 square kilometers).	BLM to Nye County	Land leased from Nye County to Nevada Science and Technology Center
Total land use impacts			
Federal land to Indian Reservations:	40 square kilometers		
Federal land to private and commercial use:	154+ square kilometers		
Private to Federal land:	25+ square kilometers (proposed as of December 2000)		

a. BLM = Bureau of Land Management; NTS = Nevada Test Site; NTSDC = NTS Development Corporation; MNS = M&N Wind Power Inc. and Siemans; NPS = National Park Service; BIA = Bureau of Indian Affairs.
b. To convert square kilometers to acres, multiply by 247.1.
c. Source: DIRS 155979-PBS&J (2001, pp. xi and xiii to xviii).
d. Source: Ivanpah Valley Public Lands Transfer Act (Public Law 106-362, 114 Stat. 1404).
e. Source: DIRS 154121-DOI (2000, Section 2.2).
f. Source: DIRS 155095-BLM (2000, pp. 1 to 13).
g. Source: DIRS 154545-DOE (2001, pp. 3-1 to 3-9).
h. Source: *Southern Nevada Public Land Management Act of 1998* (Public Law 105-263, 112 Stat. 2343).
i. Source: DIRS 155597-BLM (2000, all).
j. Source: DIRS 148148-Williams and Levy (1999, p. 1).

the Bureau has recommended acquiring about 23 square kilometers (5,800 acres) of environmentally sensitive lands throughout the State of Nevada that would be transferred from commercial and private use to general Bureau use.

Several land use conversions could result in commercial or private use of Federal lands. In addition to those lands transferred under the Southern Nevada Public Land Management Act, lands would be leased or transferred for the Ivanpah Cargo Airport, the Moapa Paiute Energy Center, the Cortez Mine, and the Desert Space Station Science Museum. These changes in land use would permit orderly development of public lands.

The projects that would occur on the Nevada Test Site and the Nellis Air Force Range would result in no net change in land use because the lands are already removed from the public use and are designated for development.

Some of the lands that would be transferred to the Timbisha Shoshone Nation could have some associated commercial use; however, this use would be consistent with the designations for the areas, and developments would be restricted to maintain the natural resources of the land.

In addition to the cumulative changes to land use and ownership, DOE considered potential conflicts with plans and policies issued by various government entities in the vicinity of the proposed Yucca Mountain Repository. In particular, DOE reviewed a number of documents issued by or in conjunction with Nye County and communities in Nye County. In general, the local governments have expressed goals that would minimize the conversion of private lands to public use. At this time DOE is not aware of any direct operational conflicts between the proposed repository and Nye County planning efforts because the Department does not foresee a need to expand the withdrawal area or for the conversion of private lands in the vicinity of the repository. Transportation-related issues are discussed in Section 8.4.2.1.

8.2.2 AIR QUALITY

8.2.2.1 Inventory Module 1 or 2 Impacts

This section addresses potential nonradiological and radiological cumulative impacts to air quality from emplacement in a repository at Yucca Mountain of the additional quantities of spent nuclear fuel and high-level radioactive waste above those evaluated for the Proposed Action, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste (that is, Inventory Modules 1 and 2). It compares potential nonradiological and radiological cumulative impacts to applicable regulatory limits, including the new U.S. Environmental Protection Agency National Ambient Air Quality Standard for particulate matter with a diameter of less than 2.5 micrometers. Chapter 3, Section 3.1.2.1, discusses the current status of this standard. Sources of nonradiological air pollutants at the proposed repository could include fugitive dust emissions from land disturbances, excavated rock handling, and concrete batch plant operations and emissions from fossil-fuel consumption.

8.2.2.1.1 *Nonradiological Air Quality*

The construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository for Inventory Module 1 or 2 would result in increased releases of criteria pollutants (nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter) and cristobalite as described in the following sections. The types of activities producing these releases would be the same as those described for the Proposed Action (see Chapter 4, Section 4.1.2).

Construction. The repository construction phase for Inventory Module 1 or 2 would produce the same levels of gaseous pollutants and cristobalite but slightly higher air concentrations of particulate matter, as listed in Table 8-7. The air concentrations would still be small fractions of the applicable regulatory limits.

Table 8-7. Estimated construction phase concentrations of criteria pollutants and cristobalite (micrograms per cubic meter).[a]

			Proposed Action			
			Maximum concentration[c,d,e]		Percent of regulatory limit[e]	
Pollutant	Averaging time	Regulatory limit[b]	Higher-temperature	Lower-temperature	Higher-temperature	Lower-temperature
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.41	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide[f]	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.042 - 0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.69	0.74 - 0.94	1.4	1.5 - 1.9
	24-hour	150 (65)	6.5	7.0 - 8.4	4.3	4.7 - 5.6
Cristobalite	Annual[g]	10[g]	0.018	0.017 - 0.018	0.18	0.17 - 0.18
			Inventory Module 1 or 2			
Nitrogen dioxide	Annual	100	0.40	0.41 - 0.42	0.40	0.41 - 0.42
Sulfur dioxide	Annual	80	0.10	0.10	0.13	0.13
	24-hour	365	1.3	1.3	0.36	0.36
	3-hour	1,300	8.5	8.6 - 8.7	0.66	0.66 - 0.67
Carbon monoxide	8-hour	10,000	4.2	4.3 - 4.4	0.041	0.043
	1-hour	40,000	29	29 - 30	0.072	0.073 - 0.075
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.81	0.85 - 1.1	1.6	1.7 - 2.1
	24-hour	150 (65)	7.1	7.4 - 8.9	4.7	4.9 - 5.8
Cristobalite	Annual[g]	10[g]	0.018	0.017 - 0.018	0.18	0.17-0.18

a. Source: Appendix G, Section G.1.4.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at the accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.4.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

Operation and Monitoring. Table 8-8 lists estimated air quality impacts from criteria pollutants and cristobalite for Inventory Module 1 or 2. The concentrations in this table are for the period of continuing surface and subsurface development and emplacement activities. During the subsequent monitoring and maintenance activities these concentrations would decrease considerably. All concentrations are comparable to those produced under the Proposed Action. All concentrations would be small fractions of the applicable regulatory limits for Module 1 or 2. Because the development of the emplacement drifts for Module 1 or 2 would take additional time compared to the Proposed Action, these releases of criteria pollutants would occur over a longer period than those from the Proposed Action. In general, the values in Table 8-8 for operation and monitoring are smaller than the values in Table 8-7 for construction because there would be more land surface disturbance during construction.

Closure. Continuing the closure of the repository for either Inventory Module 1 or 2 would produce comparable, but slightly lower, concentrations of gaseous pollutants, particulate matter, and cristobalite than those estimated for the Proposed Action. The concentrations would still be small fractions of the applicable regulatory limits (see Table 8-9). With Inventory Module 1 or 2, the amount of backfill required to close the ramps, main tunnels, and ventilation shafts would be larger than that for the Proposed Action, and the size of the excavated rock pile to reclaim would be larger. However, the

Table 8-8. Estimated operation and monitoring phase concentrations of criteria pollutants and cristobalite (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c,d,e] Higher-temperature	Maximum concentration[c,d,e] Lower-temperature	Percent of regulatory limit[e] Higher-temperature	Percent of regulatory limit[e] Lower-temperature
			Proposed Action			
Nitrogen dioxide	Annual	100	0.28	0.28 - 0.31	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.089 - 0.092	0.11	0.11 - 0.12
	24-hour	365	1.2	1.2	0.33	0.34
	3-hour	1,300	7.8	7.9 - 8.0	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.7	2.7 - 3.0	0.026	0.027 - 0.029
	1-hour	40,000	19	19 - 21	0.048	0.049 - 0.052
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.080	0.10 - 0.19	0.16	0.20 - 0.39
	24-hour	150 (65)	0.97	1.3 - 2.3	0.65	0.87 - 1.6
Cristobalite	Annual[g]	10[g]	0.0093	0.009 - 0.017	0.093	0.091 - 0.17
			Inventory Module 1 or 2			
Nitrogen dioxide	Annual	100	0.28	0.29 - 0.32	0.28	0.29 - 0.32
Sulfur dioxide	Annual	80	0.089	0.090 - 0.093	0.11	0.12
	24-hour	365	1.2	1.2 - 1.3	0.34	0.34
	3-hour	1,300	7.9	7.9 - 8.1	0.60	0.61 - 0.62
Carbon monoxide	8-hour	10,000	2.6	2.7 - 2.9	0.026	0.026 - 0.029
	1-hour	40,000	19	19 - 21	0.047	0.048 - 0.052
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.18	0.18 - 0.23	0.37	0.37 - 0.46
	24-hour	150 (65)	2.6	2.6 - 3.0	1.7	1.7 - 2.0
Cristobalite	Annual[g]	10[g]	0.011	0.010 - 0.016	0.11	0.10 - 0.16

a. Source: Appendix G, Section G.1.5.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11, and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.5.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

duration of the closure period for Inventory Module 1 or 2 would increase over that of the Proposed Action, resulting in minor changes in the air concentrations between the Proposed Action and Inventory Module 1 or 2.

8.2.2.1.2 *Radiological Air Quality*

Inventory Module 1 or 2 would require more subsurface excavation and a longer closure phase leading to increased radon releases compared to the Proposed Action. The increased quantity of spent nuclear fuel that repository facilities would receive and package would also result in additional releases of krypton-85 from failed spent nuclear fuel cladding but, as for the Proposed Action, naturally occurring radon-222 and its radioactive decay products would still be the dominant dose contributors.

The following paragraphs discuss the estimated radiological air quality impacts in terms of the potential radiation dose to members of the public and workers for the construction, operation and monitoring, and closure phases of Inventory Module 1 or 2. For these estimates, workers exposed through the air pathway would be noninvolved workers.

Construction. Table 8-10 lists estimated doses to members of the public and workers for the construction phase. These values resulting from radon releases during the 5-year construction phase

Table 8-9. Estimated closure phase concentrations of criteria pollutants and cristobalite (micrograms per cubic meter).[a]

Pollutant	Averaging time	Regulatory limit[b]	Maximum concentration[c,d,e] Higher-temperature	Maximum concentration[c,d,e] Lower-temperature	Percent of regulatory limit[d] Higher-temperature	Percent of regulatory limit[d] Lower-temperature
			Proposed Action			
Nitrogen dioxide	Annual	100	0.54	0.54	0.54	0.54 - 0.55
Sulfur dioxide	Annual	80	0.11	0.11	0.15	0.15
	24-hour	365	1.4	1.4	0.38	0.38
	3-hour	1,300	9.3	9.3	0.71	0.71 - 0.72
Carbon monoxide	8-hour	10,000	4.7	4.7	0.045	0.045 - 0.046
	1-hour	40,000	31	31	0.078	0.078
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.38	0.34 - 0.37	0.76	0.67 - 0.73
	24-hour	150 (65)	5.5	5.2 - 5.4	3.6	3.4 - 3.6
Cristobalite	Annual[g]	10[g]	0.012	0.0089 - 0.0095	0.12	0.089 - 0.098
			Inventory Module 1 or 2			
Nitrogen dioxide	Annual	100	0.51	0.48 - 0.49	0.52	0.49
Sulfur dioxide	Annual	80	0.11	0.11	0.14	0.14
	24-hour	365	1.4	1.4	0.38	0.37
	3-hour	1,300	9.1	9.0	0.70	0.69
Carbon monoxide	8-hour	10,000	4.4	4.2 - 4.3	0.043	0.041 - 0.042
	1-hour	40,000	30	28 - 29	0.075	0.071 - 0.072
PM_{10} ($PM_{2.5}$)[f]	Annual	50 (15)	0.40	0.32 - 0.35	0.079	0.65 - 0.69
	24-hour	150 (65)	5.6	5.1 - 5.2	3.7	3.4 - 3.5
Cristobalite	Annual[g]	10[g]	0.013	0.010 - 0.013	0.13	0.10 - 0.13

a. Source: Appendix G, Section G.1.6.
b. Regulatory limits for criteria pollutants from 40 CFR 50.4 through 50.11 and Nevada Administrative Code 445B.391 (see Chapter 3, Table 3-5).
c. Sum of highest concentrations at accessible land withdrawal boundary, regardless of direction.
d. Source: Chapter 4, Section 4.1.2 and Appendix G, Section G.1.6.
e. Numbers are rounded to two significant figures; therefore, the percent of regulatory limit might not equal the percent calculated from the numbers listed in the table.
f. Data on $PM_{2.5}$ not being collected at time of analysis. However, overall PM_{10} numbers are well below standard for both.
g. There are no regulatory limits for public exposure to cristobalite, a form of crystalline silica. An Environmental Protection Agency health assessment (DIRS 103243-EPA 1996, all) states that the risk of silicosis is less than 1 percent for a cumulative exposure to 1,000 micrograms per cubic meter-year. Using a 70-year lifetime, an approximate annual average concentration of 10 micrograms per cubic meter was established as a benchmark for comparison.

would be similar to those for the Proposed Action because the subsurface volume excavated would be about the same.

Operation and Monitoring. The doses from krypton-85 from receipt and packaging activities during operation and monitoring would be very low. Dose to the public would be only a fraction (0.00003 or less) of the dose from naturally occurring radon-222 and its radioactive decay products, as discussed below. Similarly, the dose to Yucca Mountain workers from krypton-85 would be a fraction (0.00001 or less) of the dose to those workers from radon-222. The annual dose from krypton-85 would be the same as that for the Proposed Action, but would occur for 38 years of spent nuclear fuel handling activities rather than 24 years.

Table 8-11 and Table 8-12 list doses to individuals and populations for operation and monitoring, respectively. In all cases, naturally occurring radon-222 would be the dominant contributor to the doses, which would increase because of the larger repository required for Inventory Module 1 or 2. Average annual doses would be higher to members of the public and higher to noninvolved workers during the 38 years of development and emplacement activities when the South Portal would be open and used for exhaust ventilation. The analysis estimated collective doses for public and worker populations for the 100 to 338 years for operation and monitoring, including the 38 years of development and emplacement activities and 62 to 300 years of monitoring and maintenance activities. The dose to the maximally exposed member of the public is for 38 years of operations and 32 years of monitoring (that is, a 70-year

Table 8-10. Estimated radiation doses to maximally exposed individuals and populations from subsurface radon-222 releases during initial construction period.[a,b,c]

Impact	Operating mode: Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Maximum annual
	Proposed Action			
Dose to public				
Offsite MEI[d] (millirem)	1.7	0.43	1.7 - 2.0	0.43 - 0.53
80-kilometer population[e] (person-rem)	33	8.4	33 - 40	8.4 - 10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[f] (millirem)	7.5	2.0	7.5 - 9.0	1.9 - 2.3
Yucca Mountain noninvolved worker population[g] (person-rem)	0.41	0.10	0.41 - 0.48	0.10 - 0.13
Nevada Test Site noninvolved worker population[h] (person-rem)	0.0013	0.00032	0.0013 - 0.0015	0.00032 - 0.00039
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	1.7	0.43	2.0	0.52 - 0.53
80-kilometer population (person-rem)	33	8.4	39 - 40	10
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker (millirem)	7.5	2.0	8.8 - 9.0	2.3
Yucca Mountain noninvolved worker population (person-rem)	0.41	0.10	0.47 - 0.49	0.12 - 0.13
Nevada Test Site noninvolved worker population (person-rem)	0.0013	0.00032	0.0015	0.00038 - 0.00039

a. Source: Appendix G, Section G.2.
b. Numbers are rounded to two significant figures.
c. Annual values are for the maximum year during the construction phase.
d. MEI = maximally exposed individual; public MEI location would be at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [about 6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Table 8-11. Estimated radiation doses to maximally exposed individuals and populations during operations activities.[a,b,c,d]

Impact	Operating mode: Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Maximum annual
	Proposed Action			
Dose to public				
Offsite MEI[e] (millirem)	12	0.73	17 - 43	1.0 - 1.3
80-kilometer population[f] (person-rem)	230	14	320 - 830	20 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[g] (millirem)	30	2.0	39 - 42	2.8 - 3.0
Yucca Mountain noninvolved worker population[h] (person-rem)	1.2	0.081	1.8 - 1.9	0.12 - 0.13
Nevada Test Site noninvolved worker population[i] (person-rem)	0.011	0.00063	0.015 - 0.043	0.00090 - 0.0012
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	22	0.94	31 - 66	1.3 - 2.2
80-kilometer population (person-rem)	430	18	600 - 1,300	26 - 42
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker (millirem)	45	2.0	62 - 95	2.8 - 4.6
Yucca Mountain noninvolved worker population (person-rem)	1.8	0.081	2.5 - 4.1	0.11 - 0.2
Nevada Test Site noninvolved worker population (person-rem)	0.02	0.00085	0.028 - 0.063	0.0012 - 0.002

a. Source: Appendix G, Section G.2.
b. Numbers are rounded to two significant figures.
c. For Inventory Module 1 or 2, the operation and monitoring phase would last 100 years for the higher-temperature operating mode and 163 to 338 years for the lower-temperature operating mode.
d. Maximum annual dose occurs during the last year of development, when repository would be largest and South Portal would still be used for exhaust ventilation.
e. MEI = maximally exposed and individual; at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. Maximally exposed noninvolved worker would be in the South Portal Development Area.
h. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
i. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

Table 8-12. Estimated radiation doses to maximally exposed individuals and populations during monitoring activities.[a,b,c,d]

Impact	Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Maximum annual
	Proposed Action			
Dose to public				
Offsite MEI[e] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population[f] (person-rem)	600	8	1,500 - 3,500	11 - 17
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker[g] (millirem)	0.096	0.0019	0.16 - 0.33	0.0011 - 0.0067
Yucca Mountain noninvolved worker population[h] (person-rem)	0.0091	0.0013	0.0031 - 0.05	0.000034 - 0.0057
Nevada Test Site noninvolved worker population[i] (person-rem)	0.033	0.00044	0.083 - 0.019	0.00021 - 0.00094
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	39	0.62	20 - 100	0.29 - 1.4
80-kilometer population (person-rem)	740	12	2,200 - 5,400	5.6 - 28
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved worker (millirem)	0.22	0.0043	0.33 - 0.54	0.0022 - 0.011
Yucca Mountain noninvolved worker population (person-rem)	0.025	0.0044	0.067 - 0.1	0.000075 - 0.0091
Nevada Test Site noninvolved worker population (person-rem)	0.041	0.00066	0.12 - 0.3	0.00031 - 0.0015

a. Source: Appendix G, Section G.2.
b. Numbers are rounded to two significant figures.
c, For Inventory Module 1 or 2, the operation and monitoring phase would last 100 years for the higher-temperature operating mode and 163 to 338 years for the lower-temperature operating mode.
d. Maximum annual dose occurs during the last year of development, when repository would be largest and South Portal would still be used for exhaust ventilation.
e. MEI = maximally exposed individual; at the southern boundary of the land withdrawal area.
f. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
g. Maximally exposed noninvolved worker would be in the South Portal Development Area.
h. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
i. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

lifetime). The dose to the maximally exposed noninvolved worker is for 50 years at the South Portal during development, emplacement, and monitoring activities.

Closure. Table 8-13 lists estimated doses to populations and maximally exposed individuals during the closure phase. Radiation doses would increase over those for the Proposed Action not only because of the larger excavated volume but also the longer time required for closure (12 to 23 years) in comparison to 10 to 17 years.

Summary. Based on the analysis of radiological air quality impacts from repository construction, operation and monitoring, and closure for Inventory Module 1 or 2, the estimated maximum annual dose to the maximally exposed individual member of the public would be 0.99 millirem for the lower-temperature operating mode during development and emplacement activities in the operation and monitoring phase. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 6.6 percent of this standard. The radiation dose is 0.3 percent of the annual 340-millirem natural background dose to individuals in Amargosa Valley. Section 8.2.7 discusses human health impacts to the public that could result from radiation exposures during construction, operation and monitoring, and closure for Inventory Module 1 or 2.

8.2.2.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

This section addresses potential nonradiological and radiological cumulative impacts to air quality from activities at the repository for the Proposed Action or Inventory Module 1 or 2 and other Federal,

Table 8-13. Estimated radiation doses to maximally exposed individuals and populations from radon-222 releases during closure phase.[a,b,c]

Impact	Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Maximum annual
	Proposed Action			
Dose to public				
MEI[d] (millirem)	3.0	0.39	4.3 - 9.4	0.57 - 0.87
80-kilometer population[e] (person-rem)	57	7.4	83 - 180	10 - 16
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved (surface) worker[f] (millirem)	0.014	0.0018	0.024 - 0.070	0.0030 - 0.0063
Yucca Mountain noninvolved (surface) worker population[g] (person-rem)	0.0040	0.00052	0.0070 - 0.015	0.00088 - 0.0014
Nevada Test Site noninvolved worker population[h] (person-rem)	0.0031	0.00041	0.0046 - 0.0099	0.00058 - 0.00089
	Inventory Module 1 or 2			
Dose to public				
MEI (millirem)	4.9	0.60	8.5 - 19	0.86 - 1.4
80-kilometer population (person-rem)	95	11	160 - 360	16 - 26
Dose to noninvolved (surface) workers				
Maximally exposed noninvolved (surface) worker (millirem)	0.034	0.0040	0.063 - 0.14	0 - 0.010
Yucca Mountain noninvolved (surface) worker population (person-rem)	0.012	0.0013	0.015 - 0.026	0.0014 - 0.0019
Nevada Test Site noninvolved worker population (person-rem)	0.0052	0.00061	0.0090 - 0.020	0.00088 - 0.00015

a. Source: Appendix G, Section G-2.
b. Numbers are rounded to two significant figures.
c. The closure phase would last 10 to 7 years for the Proposed Action and 12 to 23 years for Inventory Module 1 or 2.
d. MEI = maximally exposed individual; at the southern boundary of the land withdrawal area.
e. The population includes about 76,000 individuals within 80 kilometers (50 miles) of the repository (see Chapter 3, Section 3.1.8).
f. Maximally exposed noninvolved worker would be in the South Portal Development Area.
g. Includes noninvolved workers at the North Portal Operations Area and South Portal Development Area.
h. DOE workers at the Nevada Test Site [6,600 workers (DIRS 101811-DOE 1996, p. 5-14) 50 kilometers (30 miles) east-southeast near Mercury, Nevada].

non-Federal, and private actions that would coincide with repository operations and potentially affect the air quality within the geographic boundaries of repository air quality impacts.

To identify and quantify potential cumulative impacts on air resources from other actions, the Department used a 50-mile (80-kilometer) radius around the proposed repository as the region of influence. However, because of the distances involved and the dispersion afforded by distance and different wind directions, the potential for overlap of plumes from multiple actions would be greatest for those actions that are in close proximity to each other (that is, a few miles). Beyond that, the degree of plume overlap is less certain and indeed may not exist.

8.2.2.2.1 *Nonradiological Air Quality*

Construction, operation and monitoring, and closure of the proposed Yucca Mountain Repository would have very small impacts on regional air quality for the Proposed Action or for Inventory Module 1 or 2. Annual average concentrations of criteria pollutants at the land withdrawal boundary would be 1 percent or less of applicable regulatory limits except for PM_{10}, which the analysis estimated would be as much as 6.5 percent of the regulatory limit at the land withdrawal boundary. This estimate does not consider standard dust suppression activities (such as wetting), so actual concentrations probably would be much lower.

DOE has monitored particulate matter concentrations in the Yucca Mountain region since 1989; gaseous criteria pollutants were monitored from October 1991 through September 1995. Concentrations were well below applicable National Ambient Air Quality Standards (see Chapter 3, Section 3.1.2.1). In 1990, DOE also measured ambient air quality in several Nevada Test Site areas for short-term concentrations of sulfur dioxide, carbon monoxide, and PM_{10} (DIRS 101811-DOE 1996, Volume I, pp. 4-146 and 4-148).

The measurements were all lower than the applicable short-term (1-hour, 3-hour, 8-hour, and 24-hour) limits.

Pollutant concentrations related to Nevada Test Site activities would be well below ambient air quality standards and would not increase ambient pollutant concentrations above standards in Nye County (DIRS 101811-DOE 1996, Volume I, p. 4-146). Therefore, DOE expects the cumulative impacts from proposed repository and Nevada Test Site operations to be very small.

Other actions discussed in Section 8.1 would be unlikely to have cumulative impacts with the repository because they are sufficiently far away that plumes would have limited potential for overlap. Further, the responsible agencies would take measures for each action to minimize regional air impacts.

Repository activities would have no effect on air quality in the Las Vegas Valley air basin, which is a nonattainment area for carbon monoxide and PM_{10}, because the Las Vegas Valley air basin lies approximately 120 kilometers (75 miles) southeast of the proposed repository site.

8.2.2.2.2 *Radiological Air Quality*

Past activities at the Nevada Test Site are responsible for the seepage of radioactive gases from underground testing areas and slightly increased krypton-85 levels on Pahute Mesa in the northwest corner of the Nevada Test Site (see Figure 8-2). Some radioactivity on the site is attributable to the resuspension of soils contaminated from past aboveground nuclear weapons testing (DIRS 101811-DOE 1996, Volume I, p. 4-149). Current Nevada Test Site defense program activities have not resulted in detectable offsite levels of radioactivity. As discussed in Chapter 3, Section 3.1.8.2, estimated radiation doses to the public during 1999 were 0.12 millirem to the maximally exposed individual [a hypothetical resident of Springdale, Nevada, which is about 14 kilometers (19 miles) north of Beatty (see Figure 8-2)] and 0.38 person-rem to the population within 80 kilometers (50 miles) of Nevada Test Site airborne emission sources (DIRS 146592-Black and Townsend 1998, p. 7-1). The radiation dose estimates from repository construction, operation and monitoring, and closure (see Tables 8-10, 8-11, 8-12, and 8-13) would add to these estimates assuming the exposed individuals and population were the same (they are not). Conservatively adding the 1999 maximally exposed individual dose from the Nevada Test Site to the highest estimated average annual dose to the maximally exposed individual from repository operations (hypothetical individual located at the southern border of the land withdrawal area) (2.2 millirem) resulted in a cumulative dose of 2.3 millirem. DOE compared the estimated annual dose to the Preclosure Public Health and Environmental Standard found at 10 CFR 63.204, which is 15 millirem per year to a member of the public. The dose would be about 15 percent of this standard. This dose would also represent 0.68 percent of the annual 340-millirem natural background radiation dose to individuals in Amargosa Valley. Conservatively adding the 1999 Nevada Test Site and highest estimated annual repository population dose (42 person-rem) results in a cumulative dose of 42 person-rem. No latent cancer fatalities to the population would be expected from this cumulative exposure (see Section 8.2.7).

Chapter 3 discusses potential radiological doses from past weapons testing at the Nevada Test Site. Residents who were present during the periods when such testing (in particular, atmospheric weapons testing from the 1950s to the early 1960s) occurred could have received as much as 5 rem to the thyroid gland from iodine-131 releases. Using a tissue weighting factor of 0.03 as specified in International Commission on Radiological Protection Publication 26 (DIRS 101075-ICRP 1977, all) this equates to an effective dose equivalent of about 150 millirem. Because of the length of time since atmospheric weapons testing ended, essentially all of this dose has already occurred. This dose would apply only to those residents who lived in the region of influence during the period of atmospheric weapons testing. DOE has not added this dose to the maximally exposed individual dose, but has included this information here so long-term residents in the region of influence can evaluate their potential for impacts from past nuclear weapons testing. (DOE has also included this information in the air quality portion of Table 8-60.)

The only other activity identified in the 80-kilometer (50-mile)-radius region of influence that could affect radiological air quality is a low-level radioactive disposal site near Beatty, Nevada, which was officially closed on January 1, 1993. The physical work of a State-approved Stabilization and Closure Plan ended in July 1994. Custodianship of the site has been transferred to the State of Nevada. Monitoring is continuing at the site to ensure that any radioactive material releases to the air continue to be low (DIRS 102171-NSHD 1999, Section on the Bureau of Health Protection Services).

8.2.3 HYDROLOGY

8.2.3.1 Surface Water

Potential impacts to surface waters from the Proposed Action would be relatively minor and limited to the immediate vicinity of land disturbances associated with the action (see Chapter 4, Section 4.1.3.2, and the floodplain/wetlands assessment in Appendix L). Surface-water impacts of primary concern would include the following:

- Introduction and movement of contaminants
- Changes to runoff or infiltration rates
- Alterations of natural drainage

This section addresses these impact areas in a discussion of possible increases or other changes that could occur as a result of the emplacement of Inventory Module 1 or 2. To be cumulative, other Federal, non-Federal, or private action effects would have to occur in the immediate area because of the transient nature of the surface water from the repository (that is, stormwater runoff). No currently identified actions have met this criterion.

Introduction and Movement of Contaminants

For Inventory Module 1 or 2, there would be essentially no change in the potential for soil contamination during the construction, operation and monitoring, and closure phases. There would be no change in the types of contaminants present nor would there be changes in operations that would make spills or releases more likely. Similarly, there would be no change in the threat of flooding to cause contaminant releases beyond that described for the Proposed Action.

Changes to Runoff or Infiltration Rates

Compared to the estimated area of land disturbed under the Proposed Action, Inventory Module 1 or 2 would require the disturbance of additional land for the corresponding repository operating mode (see Table 8-4). A maximum of about 5.5 square kilometers (1,400 acres) of land would be newly disturbed for Module 1 or 2 for the lower-temperature mode if surface aging was included. This increase in disturbed land would still be a relatively small portion of the natural drainage areas and would make little difference in the amount of water that soaked into the ground or reached the intermittently flowing drainage channels. Disturbed areas not covered by structures would slowly return to conditions more similar to those of the surrounding undisturbed ground.

Alterations of Natural Drainage

No additional actions or land disturbances associated with Inventory Module 1 or 2 would involve a potential to alter noteworthy natural drainage channels in the area. The excavated rock pile and its increased size for Module 1 or 2 would be in an area that would obstruct a very small portion of overland drainage. Potential impacts to floodplains would be the same as those described for the Proposed Action (see Chapter 4, Section 4.1.3.3). The construction, operation, and maintenance of a rail line, roadways, and bridges in the Yucca Mountain vicinity could affect the 100- and 500-year floodplains of Fortymile Wash, Busted Butte Wash, Drill Hole Wash, and Midway Valley Wash at Yucca Mountain. The floodplains affected and the extent of activities in the floodplains would depend on which routes DOE selected. Appendix L contains a floodplain/wetlands assessment that describes the actions DOE could take to construct, operate, and maintain a branch rail line or highway route in the Yucca Mountain vicinity.

8.2.3.2 Groundwater

8.2.3.2.1 *Inventory Module 1 or 2 Impacts*

Potential groundwater impacts would be related to the following:

- The potential for a change in infiltration rates that could increase the amount of water in the unsaturated zone and adversely affect the performance of waste containment in the repository, or decrease the amount of recharge to the aquifer
- The potential for contaminants to migrate to the unsaturated or saturated groundwater zones during the active life of the repository
- The potential for water demands associated with the repository to deplete groundwater resources to an extent that could affect downgradient groundwater use or users

Changes to Infiltration and Aquifer Recharge. If DOE emplaced Inventory Module 1 or 2, changes related to infiltration and recharge rates would be limited to three areas: a possible increase in the size of the excavated rock pile, an increase in the number of ventilation shaft operations areas, and an extended scope for subsurface activities. The following paragraphs discuss these items.

Additional land disturbance anticipated during the operation and monitoring phase would be the continued growth of the excavated rock pile. Depending on the repository operating mode, this could involve as much as about 0.5 square kilometer (120 acres) of additional land over that required for the Proposed Action (see Table 8-4). Although the excavated rock pile could have different infiltration rates than undisturbed ground, it probably would not be a recharge location because of the extended depth of unconsolidated material, nor would it be likely to cause a large change in the amount of water that would otherwise reach recharge areas such as drainage channels.

Increased land disturbance would result from the additional ventilation shaft operation areas and the access roads that would be required as the repository footprint size increased to accommodate the Module 1 or 2 inventory. Depending on the repository operating mode, this could involve an additional 0.3 to 0.47 square kilometer (74 to 120 acres) of land disturbance over that required for these elements of the Proposed Action (see Table 8-4). These areas of disturbance would be primarily on steeper terrain, uphill from the portal areas, where unconsolidated material is likely thin and where disturbances could expose fractured bedrock. Infiltration rates could be increased notably in such areas as a result. However, much of the disturbed area would be capped with road material or equipment pads, and the amount of disturbed land would still be small in comparison to the surrounding undisturbed area.

Underground activities and their associated potential to contribute to the deep infiltration of water would be basically the same as those described for the Proposed Action, except emplacement drift construction would take an estimated 36 years to complete with either Inventory Module 1 or 2, compared to 22 years for the Proposed Action (see Table 8-3). As described for the Proposed Action, the quantities of water in the subsurface not removed to the surface by ventilation or pumping and thus available for infiltration would be small and primarily limited to the duration of drift development when the largest quantities of water would be used in the subsurface for dust control.

Potential for Contaminant Migration to Groundwater Zones. Neither Inventory Module 1 nor 2 would involve additional actions likely to increase the potential for contaminant releases to the environment. The only possible exception to this could be the extended period of subsurface excavation activities to accommodate the additional inventory. However, this exception would be an extension of activities with minimal potential to involve substantial contaminant releases.

Potential to Deplete Groundwater Resources. Anticipated annual water demand for Inventory Module 1 or 2 would be the same or very similar to that projected for the Proposed Action. Table 8-14 summarizes estimated annual water demands for both the Proposed Action and Inventory Module 1 or 2. The table indicates no notable change in water demand during construction.

Table 8-14. Estimated annual water demand (acre-feet)[a] for the Proposed Action and Inventory Module 1 or 2.

	Water demand (acre-feet/year)[a]		
		Operating mode	
Phase	Duration (years)	Higher-temperature	Lower-temperature
	Proposed Action		
Construction	5	160	190 to 210
Operation and monitoring (by activity)			
Emplacement and development activities			
Combined emplacement and development	22	230	250 to 290
Subsequent emplacement or aging only[b]	2 or 28	180	90 to 190
Monitoring activities			
Initial decontamination	3	220	200 to 230
Subsequent monitoring/caretaking	73 to 297	6	3 to 6
Closure	10 to 17	81	70 to 84
	Inventory Module 1 or 2		
Construction	5	160	190 to 210
Operation and monitoring (by activity)			
Emplacement and development activities			
Combined emplacement and development	36	250	240 to 320
Subsequent emplacement only[b]	2 or 15	180	90 to 190
Monitoring activities			
Initial decontamination	3	220	200 to 230
Subsequent monitoring/caretaking	59 to 297	6	4 to 6
Closure	12 to 23	83	73 to 91

a. To convert acre-feet to cubic meters, multiply by 1,233.49.
b. Unless surface aging is involved, the period during which development was complete and only emplacement being conducted would last 2 years. This higher duration listed is applicable only to the lower-temperature repository operating mode that includes surface aging.

Projected annual water demand during emplacement and development activities of the operation and monitoring phase (as listed in Table 8-14) would be very similar, but generally a little higher under Inventory Module 1 or 2. However, the difference in total water demand would be greater when the change in the duration of the annual demand is taken into consideration. That is, this phase of repository activities, which would have the highest annual water demand, is extended from 22 to 36 years with the Module 1 or 2 inventory. On an annual basis, water demand would increase no more than 4 to 10 percent over that for the Proposed Action but, during the entire 36-year period, Inventory Module 1 or 2 would result in an increased water demand by as much as about 80 percent, depending on the repository operating mode.

Projected annual water demand during monitoring activities of the operation and monitoring phase would be basically the same under either the Proposed Action or Inventory Module 1 or 2. In either case, the relatively high demands listed in Table 8-14 would last only about 3 years during surface facility decontamination, after which the annual demand would drop drastically for the remainder of this long-duration activity. The closure phase for Module 1 or 2 shows there would be only a slight increase in projected annual water demand in comparison to the Proposed Action. The fact that the duration of the closure phase would be longer under Module 1 or 2 would increase the difference on a total-phase basis, but the increases would still be minor.

Potential impacts to water resources under Inventory Module 1 or 2 would be very similar to those under the Proposed Action because the annual water demand would change little, and the best understanding of the groundwater resource is that it is replenished on an annual basis as gauged by the perennial yield of the groundwater basin. Under Module 1 or 2, the repository's annual water demand from the western two-thirds of the Jackass Flats basin would remain below the lowest estimated value for its perennial yield of [720,000 cubic meters (580 acre-feet)] (see Chapter 3, Table 3-11). See Chapter 4, Section 4.1.3.3 for more information on regional groundwater usage and demand.

8.2.3.2.2 *Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions*

Potential impacts to groundwater, as described in Chapter 4, Section 4.1.3.3, and in Section 8.2.3.2.1, for the Proposed Action and Inventory Module 1 or 2 would be small and limited to the immediate vicinity of land disturbances associated with the action. The exceptions to this would be the potential impact from water demands on groundwater resources and potential impacts from contaminants in groundwater. With these exceptions, other Federal, non-Federal, or private action effects would have to occur in the same region of influence to be cumulative with those resulting from the Proposed Action or Inventory Module 1 or 2, and no currently identified actions meet this criterion.

The remainder of this discussion addresses potential impacts to groundwater resources from water demand. Section 8.3 addresses long-term impacts of contaminants in groundwater.

The discussion of impacts to groundwater resources in Chapter 4, Section 4.1.3.3, includes ongoing water demands from Area 25 of the Nevada Test Site. Area 25 is the proposed location of the primary repository surface facilities. It is also the location of wells J-12 and J-13, which would provide water for the Proposed Action and for ongoing Nevada Test Site activities in this area. The estimated water demand for these ongoing activities is 340,000 cubic meters (280 acre-feet) a year (DIRS 103226-DOE 1998, Table 11-2, p. 11-6).

Water demand during emplacement and development activities of the operation and monitoring phase under Inventory Module 1 or 2 combined with the baseline demands from Nevada Test Site activities would exceed the lowest perennial yield estimate under the lower-temperature repository operating modes if certain features were enacted. The highest annual water demand attributed to the lower-temperature operating mode with maximum package spacing, in combination with ongoing Nevada Test Site water demands, would exceed the lowest estimate of perennial yield, but only marginally. The worst-case scenario for repository water demand (maximum spacing and surface aging under the lower-temperature operating mode) added to the Nevada Test Site demand would total about 240,000 cubic meters (600 acre-feet) per year compared to 720,000 cubic meters (580 acre-feet), the lowest estimate of perennial yield for the western two-thirds of Jackass Flats. Besides these exceptions, the combined water demands would be below the lowest estimate of perennial yield. None of the water demand estimates would approach the high estimate of perennial yield for the entire Jackass Flats hydrographic basin, which is 4.9 million cubic meters (4,000 acre-feet) (see Chapter 3, Table 3-11). Potential impacts to groundwater resources from this combined demand would be no different than those described in Chapter 4, Section 4.1.3.3. That is, some decline in the water level would be likely near the production wells, and water elevation decreases at the town of Amargosa Valley would probably be no more than 0.4 to 1.1 meter (1.2 to 3.6 feet) (see Section 4.1.3.3). The reduction in underflow from the Jackass Flats hydrographic area to the Amargosa Desert hydrographic area would be less than the quantity of water actually withdrawn from the upgradient area because there would probably be minor changes in groundwater flow patterns as the water level adjusted to the withdrawals. Groundwater flow models predict the reduction in underflow to the Amargosa Desert would be no higher than 160,000 to 180,000 cubic meters (130 to 150 acre-feet) per year (see Section 4.1.3.3).

The Nevada Test Site EIS (DIRS 101811-DOE 1996, pp. 3-18, 3-19, and 3-34) indicates that the potential construction and operation of a Solar Enterprise Zone facility would represent the only action that would cause water withdrawals on the Test Site to exceed past levels. That EIS estimates that this demand would be greater than the highest estimates of the basin's perennial yield. Therefore, cumulative impacts from the Solar Enterprise Zone facility are likely. DOE is considering several locations for the Solar Enterprise Zone facility, one of which is Area 25. If DOE built this facility in Area 25, it would obtain water from the Jackass Flats hydrologic area, and possibly from other hydrologic areas.

Cumulative demands on the Jackass Flats hydrographic area could have long-term impacts on water availability in the downgradient aquifers beneath the Amargosa Desert. The groundwaters in these areas are hydraulically linked, but the exact nature and extent of that link is still a matter of study and some speculation. However, the amount of water already being withdrawn in the Amargosa Desert [averaging about 17 million cubic meters (14,000 acre-feet) of water per year from 1995 through 1997 (see Chapter 3, Table 3-11)] is much greater than the quantities being considered for withdrawal from Jackass Flats. If water pumpage from Jackass Flats affected water levels in the Amargosa Desert, the impacts would be small in comparison to those caused by local pumping in that area.

A report from the Nye County Nuclear Waste Repository Office (DIRS 103099-Buqo 1999, pp. 39 to 53) provides a perspective of potential cumulative impacts with that County as the center of interest. The Nye County report evaluates impacts to all water resources potentially available in the entire county, whereas this EIS focuses principally on impacts to the Jackass Flats groundwater basin (the source of water that DOE would use for the repository) and the groundwater system that could become contaminated thousands of years in the future. Nye County reports that the potential cumulative impacts would include additive contamination as radionuclides ultimately reached the groundwater, constraints on development of groundwater due to land withdrawal, and reduction of water available for Nye County development because of use by Federal agencies (DIRS 103099-Buqo 1999, pp. 49 to 51).

8.2.4 BIOLOGICAL RESOURCES

Impacts to biological resources from Inventory Module 1 or 2 would be similar to impacts that would occur as a result of the Proposed Action evaluated in Chapter 4, Section 4.1.4. Those impacts would occur primarily as a result of site clearing, placement of material in the excavated rock pile, habitat loss, and the loss of individuals of some animal species during site clearing and from vehicle traffic.

Inventory Module 1 or 2 would require disturbing biological resources in a larger area under each thermal load scenario than would be disturbed under the Proposed Action, primarily because the excavated rock pile would be larger (Table 8-15).

Repository construction and the excavated rock pile to support Inventory Module 1 or 2 would disturb up to 5.5 square kilometers of previously undisturbed land. Disturbances would occur in areas dominated by Mojave mixed scrub and salt desert scrub land cover types. These cover types are widespread in the withdrawal area and in Nevada. This disturbed area is larger than that for the Proposed Action and would

Table 8-15. Area of land cover types in analyzed withdrawal area disturbed by construction and the excavated rock pile (square kilometers).[a,b,c]

Land cover type	Area in Nevada	Area in analyzed withdrawal area[d]	Operating mode: Higher-temperature	Operating mode: Lower- temperature
		Proposed Action		
Blackbrush	9,900	140	0.0	0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	2.2	2.4 - 3.6
Sagebrush	67,000	16	0.0	0
Salt desert scrub	58,000	20	0.0	0
Previously disturbed[e]	NA[f]	4	1.5	1.5
Totals	***NA***	***600***	***4.3***	***4.5 - 6***
		Inventory Module 1 or 2		
Blackbrush	9,900	140	0.0	0 - 0.2
Creosote-bursage	15,000	300	0.6	0.6 - 0.7
Mojave mixed scrub	5,700	120	3.0	3.2 - 4.6
Sagebrush	67,000	16	0.0	0
Salt desert scrub	58,000	20	0.0	0
Previously disturbed[e]	NA	4	1.5	1.5
Totals	***NA***	***600***	***5.1***	***5.4 - 7***

a. Source: Facility diagrams from DIRS 104523-CRWMS M&O (1999, Figures 6.1.7-1, 6.1.7-2, 6.2.7-1, and 6.2.7-2; pp. 6-42, 6-43, 6-84, and 6-85) overlain on the land cover types map; DIRS 104589-CRWMS M&O (1998, p. 9 as adapted) using a Geographic Information System.
b. To convert square kilometers to acres, multiply by 247.1.
c. Totals might differ from sums of values due to rounding.
d. A small area [0.016 square kilometer (4 acres)] of the pinyon-juniper-2 land cover type occurs in the analyzed land withdrawal area, but would not be affected.
e. Estimate of land previously disturbed in support of the proposed repository.
f. NA = not applicable.

affect vegetation on approximately 1 percent of the previously undisturbed land within the land withdrawal area.

Releases of radioactive materials would not adversely affect biological resources. Routine releases would consist of noble gases, primarily krypton-85 and radon-222. These gases would not accumulate in the environment around Yucca Mountain and would result in low doses to plants or animals.

Overall impacts to biological resources from Inventory Module 1 or 2 would be very small. Species at the repository site are generally widespread throughout the Mojave or Great Basin Deserts and repository activities would affect a very small percentage of the available habitat in the region. Changes in the regional population of any species would be undetectable and no species would be threatened with extinction. The removal of vegetation from the small area required for Module 1 or 2 or the local loss of small numbers of individuals of some species due to site clearing and vehicle traffic would not affect regional biodiversity and ecosystem function. The loss of desert tortoise habitat and small numbers of tortoises under Module 1 or 2 would have no impact on recovery efforts for this threatened species.

Activities associated with other Federal, non-Federal, and private actions in the region should not add measurable impacts to the overall impact on biological resources. However, as stated in the Nevada Test Site EIS (DIRS 101811-DOE 1996, p. 6-16), cumulative impacts to the desert tortoises would occur throughout the region, although the intensity of the impacts would vary from location to location. The largest impact to the habitat probably would occur in the Las Vegas Valley region. The Clark County Desert Conservation Plan authorizes the taking of all tortoises on 445 square kilometers (110,000 acres) of non-Federal land in the County, and on 12 square kilometers (3,000 acres) disturbed by Nevada

Department of Transportation activities in Clark and adjacent counties. The plan also authorizes several recovery units designed to optimize the survival and recovery of this threatened species. Potential land disturbance activities at the Nevada Test Site under the expanded use alternative represent a small amount of available desert tortoise habitat and will not add measurably to the loss of this species (DIRS 101811-DOE 1996, p. 6-16). As discussed in Chapter 4, Section 4.1.4, repository construction activities would involve the loss of an amount of desert tortoise habitat that would be small in comparison to its range. Yucca Mountain is at the northern end of the range of this species. DOE anticipates that small numbers of tortoises would be killed inadvertently by vehicle traffic during the repository construction, operation and monitoring, and closure phases.

8.2.5 CULTURAL RESOURCES

The only identified actions that could result in cumulative cultural resource impact in the Yucca Mountain site vicinity are Inventory Module 1 or 2. The emplacement of either module would require small additional disturbances to land in areas already surveyed during site characterization activities (see Table 8-4). Because repository construction, operation and monitoring, and closure would be Federal actions, DOE would identify and evaluate cultural resources, as required by Section 106 of the National Historic Preservation Act, and would take appropriate measures to avoid or mitigate adverse impacts to such resources. As a consequence, archaeological information gathered from artifact retrieval during land disturbance would contribute additional cultural resources information to the regional data base for understanding past human occupation and use of the land. However, there would be a potential for illicit or incidental vandalism of archaeological or historic sites and artifacts as a result of increased activities in the repository area, which would be extended for Module 1 or 2 (see Table 8-3), and this could contribute to an overall loss of regional cultural resources information.

The Native American view of resource management and preservation is holistic in its definition of cultural resources, incorporating all elements of the natural and physical environment in an interrelated context (DIRS 102043-AIWS 1998, all). The Native American perspective on cultural resources is further discussed in Chapter 3, Section 3.1.6. Potential impacts resulting from the Proposed Action described in Chapter 4, Section 4.1.5, would also apply to Inventory Module 1 or 2.

8.2.6 SOCIOECONOMICS

8.2.6.1 Inventory Modules 1 and 2 Impacts

This section addresses potential socioeconomic impacts associated with Inventory Module 1 or 2 and concludes that impacts for Inventory Module 1 or 2 would be essential the same during construction phase as the Proposed Action, slightly greater during the development and emplacement phases than the Proposed Action, the same during the monitoring phase, and slightly greater than impacts for the Proposed Action during the closure phase. The impacts in all phases for Module 1 or 2 would be small, as are impacts estimated for the Proposed Action (see Chapter 4, Section 4.1.6). DOE analyzed both the higher-temperature operating mode and the lower-temperature operating mode. Table 8-16 summarizes the peak direct employment levels during all phases for the Proposed Action and for the Inventory Modules.

Construction

DOE expects the construction phase to last for 5 years. The construction phase for Inventory Module 1 or 2 would require approximately 1,800 workers in the peak year, the same as the Proposed Action (see Table 8-16). The impacts for Module 1 or 2 would therefore be the same as those for the Proposed Action.

Table 8-16. Estimated peak direct employment level impacts from repository phases.[a,b]

Phase	Proposed Action: Higher-temperature	Proposed Action: Lower-temperature	Inventory Module 1 or 2: Higher-temperature	Inventory Module 1 or 2: Lower-temperature
Construction	1,800	1,800	1,800	1,800
Operation and Monitoring				
Development, emplacement	1,700	1,800 - 1,900	1,700	1,700 - 2,600
Monitoring[c]	120	40 - 120	140	130 - 140
Closure	960	960	970	1,100 - 1,200

a. Includes approximately 220 currently employed workers.
b. Numbers rounded to two significant places.
c. Excludes approximately 1,100 workers required for decontamination (monitoring period). Number of required workers is approximately the same for both operating modes for Inventory Module 1 or 2.

Operation and Monitoring

For the Proposed Action, DOE expects the repository development to last for 22 years and emplacement to last for 24 years. With Modules 1 or 2, development would last 36 years and emplacement 38 years. If a design with an aging facility were selected, emplacement activities would last 50 years for the Proposed Action or 51 years for Module 1 or 2. Monitoring activities occur concurrently and then extend beyond the emplacement period for up to 300 years. Employment levels for Module 1 or 2 during this phase could require approximately 700 more workers than the estimated worker requirement for the Proposed Action (see Table 8-16). Although the overall duration of the operation phase, including the development, emplacement, and monitoring activities, varies in length depending on the final scenario of the flexible design, the primary difference between Inventory Module 1 or 2 and the Proposed Action is the increased duration of development and emplacement activities (by 14 years).

The annualized impacts during development and emplacement activities for Inventory Module 1 or 2 would be similar to those for the Proposed Action, but these impacts would continue for an additional 14 years. As with the Proposed Action, direct and indirect increases in regional employment, population, Gross Regional Product, real disposal income, and government expenditures would be small, 3 percent or less of the baselines, for affected counties. No substantial socioeconomic impacts would be likely during the operations phase.

Closure

DOE expects the closure phase to last between 12 and 23 years. Although the required staffing level for Inventory Module 1 or 2 would be slightly greater, but similar in impact, to that of the Proposed Action, Inventory Module 1 or 2 would require more time. Closure would last up to 23 years for Inventory Module 1 or 2. However, as with the Proposed Action, because work force demands would be less than the peak year employment demands during the operations or construction phase, impacts to regional employment, population, Gross Regional Product, real disposal income, and government expenditures would be very small. No substantial impact would likely occur during the closure for Inventory Module 1 or 2.

8.2.6.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

Reasonably foreseeable future actions at the Nevada Test Site could affect the socioeconomic region of influence (Nye, Clark, and Lincoln Counties). Sections 8.1.1 and 8.1.2 discuss other activities in the region that could have a socioeconomic impact. However, most of these activities have either already occurred or would occur prior to peak employment associated with the proposed repository. Because of the minimal amount of overlap that would occur in the activities, the affected communities would have more time to assimilate any new residents that might relocate to the region. Thus, no substantial impacts would be likely to occur from these activities.

8.2.7 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

This section discusses the short-term health and safety impacts to workers and to members of the public (radiological only) associated with construction, operation and monitoring, and closure activities at the Yucca Mountain site for Inventory Module 1 or 2 (Sections 8.2.7.1 through 8.2.7.3). Section 8.2.7.4 provides a summary of these impacts. Appendix F contains the approach and methods used to estimate the health and safety impacts and additional detailed results for Module 1 or 2 health and safety impacts to workers.

With one exception, no other Federal, non-Federal, or private actions were identified with spatially or temporally coincident short-term impacts in the region of influence that would result in cumulative health and safety impacts with those of the proposed Yucca Mountain Repository. Chapter 3 discusses the potential radiological doses from past weapons testing at the Nevada Test Site. While all of the current population was not present at the time of the testing, residents who were present during the time periods when weapons testing (in particular, atmospheric weapons testing from the 1950s to the early 1960s) occurred could have received as much as 5 rem to the thyroid gland from iodine-131 releases. Using a tissue-weighting factor of 0.03 as specified in International Commission on Radiological Protection Publication 26 (DIRS 101075-ICRP 1977, all), this would equate to an effective dose equivalent of about 150 millirem. Because of the length of time since atmospheric weapons testing ceased, essentially all of this dose has already occurred. This dose would apply only to those residents who lived in the region of influence during the time period of atmospheric weapons testing. DOE has not added this dose to the maximally exposed individual dose, but DOE has included this information so that long-term residents in the region of influence can evaluate their potential for impacts from past nuclear weapons testing. (The dose is included in the risk estimates in Table 8-60 for the summary of public health and safety.)

With the increased number of persons living and working in the region, the number of injuries and fatalities from nonrepository-related activities would increase. However, injury and mortality incidence should remain unchanged or decrease, assuming the continued enforcement of occupational and public health and safety regulations.

Regarding the health and safety impact analysis for Inventory Module 1 or 2, the radiological characteristics of the spent nuclear fuel and high-level radioactive waste would be the same as those for the Proposed Action; there just would be more material to emplace. As described in Appendix A, the radioactive inventory (and radiological properties) of the Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste is much less than that for spent nuclear fuel and high-level radioactive waste. Therefore, the subsurface emplacement of the material in Inventory Module 2 would not greatly increase radiological impacts to workers over those estimated for Module 1. For the surface facility evaluation, the number of workers would be the same for Inventory Module 1 or 2 (DIRS 104508-CRWMS M&O 1999, Section 3.3, third paragraph). Therefore, DOE did not perform separate impact analyses for Modules 1 and 2.

The primary changes in the parameters that would affect the magnitude of the worker health and safety impacts between the Proposed Action and Inventory Module 1 or 2 would be the periods required to perform the work and the numbers of workers for the different phases. Appendix F, Table F-43 p. 2 contains a detailed breakdown of the estimates for the involved and noninvolved workforce for the repository phases for Inventory Module 1 or 2 in terms of full-time equivalent worker-years.

For the public, the principal changes in parameters that would affect the magnitude of the health impact estimates would be the length of the various phases and the rate at which air would be exhausted from the repository. The exhaust rate of the subsurface ventilation system would affect both the radon-222 concentrations to which subsurface workers would be exposed and the quantity of radon-222 released to the environment. Appendix G, Section G.2.3.1, discusses radon-222 concentrations in the subsurface environment and release rates to the environment from the various project phases.

8.2.7.1 Construction

This section presents estimates of health and safety impacts to repository workers and members of the public for the construction phase. The values are similar to those for the Proposed Action because the length of the construction phase would be the same and activities would be similar.

Industrial Hazards

Table 8-17 lists health and safety hazards to workers common to the workplace. They are based on the health and safety loss statistics listed in Appendix F, Tables F-4 and F-5. For Inventory Module 1 or 2 these impacts would be independent of the operating mode because the number of workers would be the same for both operating modes.

Table 8-17. Summary of industrial hazard health and safety impacts to facility workers during the construction phase.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved worker		
Total recordable cases of injury and illness	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers		
Total recordable cases of injury and illness	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	340	340 - 370
Lost workday cases	160	160 - 180
Fatalities	0.16	0.16 - 0.18
Noninvolved worker		
Total recordable cases of injury and illness	55	55 - 61
Lost workday cases	27	27 - 30
Fatalities	0.048	0.048 - 0.054
All workers		
Total recordable cases of injury and illness	400	400 - 430
Lost workday cases	190	190 - 210
Fatalities	0.21	0.21 - 0.23

a. Source: Appendix F, Table F-12.

Radiological Health Impacts

This analysis presents radiological health impacts in terms of doses and resultant latent cancer fatalities. Estimated doses were converted to estimates of latent cancer fatality using a dose-to-risk conversion factor of 0.0004 and 0.0005 latent cancer fatality per person-rem for workers and the public, respectively (see Appendix F, Section F.1.1.5).

Workers. Spent nuclear fuel and high-level radioactive waste would not be present during the construction phase. Potential radiological impacts to surface workers during this phase would be limited to those from releases of naturally occurring radon-222 and its decay products with the subsurface ventilation exhaust (these impacts are presented in Section 8.2, Table 8-10). Subsurface workers would incur exposure from radiation resulting from radionuclides in the walls of the drifts and from inhalation of radon-222 in the subsurface atmosphere. Surface worker exposure would be very small compared to those for subsurface workers. The radiological doses and health impacts for Inventory Module 1 or 2 are listed in Table 8-18. The Module 1 or 2 impacts would be independent of the operating mode because the subsurface workforce would not change.

Table 8-18. Summary of radiological health impacts to workers from all activities during construction phase.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature
	Proposed Action	
Involved worker		
Dose to maximally exposed worker (millirem)	1,300	1,300
Probability of latent cancer fatality	0.00052	0.00052
Collective dose (person-rem)	680	680
Number of latent cancer fatalities	0.27	0.27
Noninvolved worker		
Dose to maximally exposed worker (millirem)	330	330
Probability of latent cancer fatality	0.00013	0.00013
Collective dose (person-rem)	37	37
Number of latent cancer fatalities	0.015	0.015
All workers		
Collective dose (person-rem)	720	720
Number of latent cancer fatalities	0.29	0.29
	Inventory Module 1 or 2	
Involved worker		
Dose to maximally exposed worker (millirem)	1,300	1,300
Probability of latent cancer fatality	0.00052	0.00052
Collective dose (person-rem)	680	680
Number of latent cancer fatalities	0.27	0.27
Noninvolved worker		
Dose to maximally exposed worker (millirem)	330	330
Probability of latent cancer fatality	0.00013	0.00013
Collective dose (person-rem)	37	37
Number of latent cancer fatalities	0.015	0.015
All workers		
Collective dose (person-rem)	720	720
Number of latent cancer fatalities	0.29	0.29

a. Source: Appendix F, Table F-11.

Public. Potential radiological impacts to the public during the construction phase would be limited to those from the release of naturally occurring radon-222 with the exhaust from subsurface ventilation. Table 8-19 presents radiological health impacts for the public surrounding the proposed repository.

8.2.7.2 Operations

This section presents estimates of health and safety impacts to workers and members of the public during the operations period. The primary differences between Inventory Module 1 or 2 and the Proposed Action would be the longer durations for development and emplacement activities. Under Module 1 or 2,

Table 8-19. Radiological health impacts to the public from the construction phase.[a]

Impact	Higher-temperature Total	Higher-temperature Maximum annual	Lower-temperature Total	Lower-temperature Annual
	Proposed Action			
Dose to public				
Offsite MEI[b] (millirem)	1.7	0.43	1.7 - 2	0.43 - 0.53
80-kilometer population (person-rem)	33	8.4	33 - 40	8.4 - 10
Offsite MEI probability of latent cancer fatality	8.5×10^{-7}	2.1×10^{-7}	8.5×10^{-7} - 0.000001	2.1×10^{-7} - 2.6×10^{-7}
80-kilometer population number of latent cancer fatalities	0.017	0.0042	0.017 - 0.02	0.0042 - 0.0052
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	1.7	0.43	2	0.52 - 0.53
80-kilometer population (person-rem)	33	8.4	39 - 40	10
Offsite MEI probability of latent cancer fatality	8.5×10^{-7}	2.1×10^{-7}	9.9×10^{-7} - 0.000001	2.6×10^{-7} - 2.6×10^{-7}
80-kilometer population number of latent cancer fatalities	0.017	0.0042	0.019 - 0.02	0.0051 - 0.0052

a. Sources: Chapter 4, Table 4-23; Appendix G, Section G.2.
b. MEI = maximally exposed individual.

it would take DOE 14 more years to complete drift development (36 years total) than for the Proposed Action and 14 more years to complete emplacement (38 years total) than for the Proposed Action.

Industrial Hazards

Table 8-20 lists health and safety impacts to workers from industrial hazards common to the workplace. These impacts would be about 50 to 60 percent greater than those calculated for the Proposed Action.

Radiological Impacts

Workers. Table 8-21 lists radiological doses and health impacts to workers during the operations period for Inventory Module 1 or 2. Appendix F contains additional detail and presents the radiological impacts for surface workers, subsurface workers, and monitoring activities. Radiological impacts to workers for Module 1 or 2 would be about 50 to 60 percent greater than those for the Proposed Action.

Public. Potential radiological impacts to the public from the operations period would result from the release of naturally occurring radon-222 and its decay products with the subsurface exhaust ventilation air and from radioactive gases, principally krypton-85, that could be released from the Waste Handling Building during spent nuclear fuel handling operations.

Table 8-22 lists the total radiological doses and radiological health impacts to the public from releases to the atmosphere of krypton-85 and radon-222 during the operations period. Radon-222 and its decay products would be the dominant dose contributors (greater than 99 percent).

8.2.7.3 Monitoring

This section contains estimates of the health and safety impacts to workers and members of the public for the monitoring period. The length of this period would depend on the operating mode; however, the monitoring phase for Inventory Module 1 or 2 would generally be shorter than the corresponding monitoring phase for the Proposed Action as shown in Table 8-3.

Industrial Hazards

Table 8-23 lists health and safety impacts to workers from hazards common to the workplace. As discussed above, the duration of the monitoring period for the Inventory Modules is shorter than that for the Proposed Action; therefore, the industrial safety impacts would be less for the Inventory Modules than for the Proposed Action.

Table 8-20. Summary of industrial hazard health and safety impacts to facility workers during operations period.

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	1,200	1,200 - 1,700
Lost workday cases	590	620 - 840
Fatalities	0.9	0.91 - 1.4
Noninvolved worker		
Total recordable cases of injury and illness	300	310 - 470
Lost workday cases	150	150 - 230
Fatalities	0.31	0.31 - 0.45
All workers		
Total recordable cases of injury and illness	1,500	1,500 - 2,200
Lost workday cases	740	770 - 1,100
Fatalities	1.2	1.2 - 1.9
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	1,900	1,900 - 2,200
Lost workday cases	970	970 - 1,100
Fatalities	1.4	1.4 - 1.7
Noninvolved worker		
Total recordable cases of injury and illness	470	470 - 560
Lost workday cases	230	230 - 270
Fatalities	0.46	0.46 - 0.54
All workers		
Total recordable cases of injury and illness	2,400	2,400 - 2,800
Lost workday cases	1,200	1,200 - 1,400
Fatalities	1.9	1.9 - 2.2

a. Source: Appendix F, Tables F-22 and F-52.

Radiological Impacts

Workers. Table 8-24 lists radiological doses and health impacts from activities during the monitoring period. During this period the primary source of collective dose to the involved subsurface worker population would be the inhalation dose from radon-222 while the primary source of collective dose to the involved surface worker population would be direct exposure to the waste packages.

Public. Table 8-25 lists the radiological doses and health impacts to the public from activities during the monitoring period. The primary source of these impacts is the release of radon-222 via subsurface ventilation flow.

8.2.7.4 Closure

This section contains estimates of health and safety impacts to workers and members of the public for the closure phase.

Industrial Hazards

Table 8-26 lists health and safety impacts to workers from hazards common to the workplace. The impacts for Inventory Module 1 or 2 would be slightly greater than those for the Proposed Action.

Radiological Impacts

Workers. Table 8-27 lists radiological doses and health impacts to workers during the closure phase. Subsurface workers would be exposed to radon-222 from inhalation of air in the drifts, to external

Table 8-21. Summary of radiological health impacts to workers from all activities during operations period.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Dose to maximally exposed worker (millirem)	15,000	15,000 - 30,000
Probability of latent cancer fatality	0.006	0.006 - 0.012
Collective dose (person-rem)	7,500	7,600 - 12,000
Number of latent cancer fatalities	3.0	3.0 - 4.8
Noninvolved worker		
Dose to maximally exposed worker (millirem)	1,500	1,500 - 1,800
Probability of latent cancer fatality	0.0006	0.0006 - 0.00072
Collective dose (person-rem)	150	160 - 170
Number of latent cancer fatalities	0.06	0.064 - 0.068
All workers		
Collective dose (person-rem)	7,700	7,800 - 12,000
Number of latent cancer fatalities	3.1	3.1 - 4.8
	Inventory Module 1 or 2	
Involved worker		
Dose to maximally exposed worker (millirem)	24,000	24,000 - 33,000
Probability of latent cancer fatality	0.0096	0.0096 - 0.013
Collective dose (person-rem)	12,000	12,000 - 15,000
Number of latent cancer fatalities	4.8	4.8 - 6
Noninvolved worker		
Dose to maximally exposed worker (millirem)	2,400	2,400
Probability of latent cancer fatality	0.00096	0.00096
Collective dose (person-rem)	180	180 - 190
Number of latent cancer fatalities	0.072	0.072 - 0.076
All workers		
Collective dose (person-rem)	12,000	12,000 - 15,000
Number of latent cancer fatalities	4.8	4.8 - 6

a. Source: Appendix F, Tables F-23 and F-53.

Table 8-22. Radiological health impacts to the public from the operations period.

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Annual
	Proposed Action			
Dose to public				
Offsite MEI[a] (millirem)	12	0.73	17 - 43	1 - 1.3
80-kilometer population (person-rem)	230	14	320 - 830	20 - 26
Offsite MEI probability of latent cancer fatality	0.000006	3.7×10^{-7}	8.3×10^{-6} - 0.000022	5.2×10^{-7} - 6.7×10^{-7}
80-kilometer population number of latent cancer fatalities	0.12	0.0071	0.16 - 0.42	0.01 - 0.013
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	22	0.94	31 - 66	1.3 - 2.2
80-kilometer population (person-rem)	430	18	600 - 1,300	26 - 42
Offsite MEI probability of latent cancer fatality	0.000011	4.7×10^{-7}	0.000016 - 0.000033	6.7×10^{-7} - 1.1×10^{-6}
80-kilometer population number of latent cancer fatalities	0.22	0.0091	0.3 - 0.64	0.013 - 0.021

a. MEI = maximally exposed individual.

Table 8-23. Summary of industrial hazard health and safety impacts to facility workers during monitoring period.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	320	400 - 1,000
Lost workday cases	130	160 - 410
Fatalities	0.31	0.38 - 1
Noninvolved worker		
Total recordable cases of injury and illness	55	65 - 150
Lost workday cases	27	32 - 73
Fatalities	0.049	0.057 - 0.13
All workers		
Total recordable cases of injury and illness	380	470 - 1,200
Lost workday cases	160	190 - 480
Fatalities	0.36	0.44 - 1.1
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	290	450 - 1,100
Lost workday cases	120	180 - 440
Fatalities	0.28	0.43 - 1.1
Noninvolved worker		
Total recordable cases of injury and illness	51	74 - 160
Lost workday cases	25	36 - 78
Fatalities	0.045	0.065 - 0.14
All workers		
Total recordable cases of injury and illness	340	520 - 1,300
Lost workday cases	150	220 - 520
Fatalities	0.33	0.50 - 1.2

a. Source: Appendix F, Tables F-31 and F-59.

radiation from radionuclides in the rock in the drift walls, and to external radiation emanating from the waste packages.

Public. Potential radiation-related health impacts to the public from closure activities would result from releases of radon-222 in the subsurface ventilation flow. Section 8.2.2.1.2 describes radiation doses to the public for this phase. Table 8-28 lists radiological dose and health impacts for the closure phase. Radiological health impacts to the public for the inventory modules would be greater than those for the Proposed Action largely because of the longer time period for closure activities (see Table 8-3).

8.2.7.5 Summary

This section contains three summary tables:

- A summary of health impacts to workers from industrial hazards common to the workplace for all phases (Table 8-29)
- A summary of radiological doses and health impacts to workers for all phases (Table 8-30)
- A summary of radiological doses and health impacts to the public for all phases (Table 8-31)

Table 8-24. Summary of radiological health impacts to workers from all activities during monitoring period.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved workers		
Dose to maximally exposed worker (millirem)	18,000	18,000
Probability of latent cancer fatality	0.0072	0.0072
Collective dose (person-rem)	1,100	1,500 - 4,300
Number of latent cancer fatalities	0.44	0.6 - 1.7
Noninvolved workers		
Dose to maximally exposed worker (millirem)	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072
Collective dose (person-rem)	36	46 - 140
Number of latent cancer fatalities	0.014	0.018 - 0.056
All workers		
Collective dose (person-rem)	1,100	1,500 - 4,400
Number of latent cancer fatalities	0.44	0.6 - 1.8
	Inventory Module 1 or 2	
Involved workers		
Dose to maximally exposed worker (millirem)	18,000	18,000
Probability of latent cancer fatality	0.0072	0.0072
Collective dose (person-rem)	990	1,700 - 4,500
Number of latent cancer fatalities	0.4	0.68 - 1.8
Noninvolved workers		
Dose to maximally exposed worker (millirem)	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072
Collective dose (person-rem)	31	56 - 150
Number of latent cancer fatalities	0.012	0.022 - 0.06
All workers		
Collective dose (person-rem)	1,000	1,800 - 4,700
Number of latent cancer fatalities	0.4	0.72 - 1.9

a. Source: Appendix F, Table F-32 and F-60.

Table 8-25. Radiological health impacts to the public from the monitoring period.

Impact	Operating mode			
	Higher-temperature		Lower-temperature	
	Total	Maximum annual	Total	Annual
	Proposed Action			
Dose to public				
Offsite MEI[a] (millirem)	29	0.41	30 - 62	0.59 - 0.89
80-kilometer population (person-rem)	600	8	1,500 - 3,500	11 - 17
Offsite MEI probability of latent cancer fatality	0.000015	2.1×10^{-7}	0.000015 - 0.000031	3×10^{-7} - 4.4×10^{-7}
80-kilometer population number of latent cancer fatalities	0.3	0.004	0.75 - 1.7	0.0057 - 0.0085
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	39	0.62	20 - 100	0.29 - 1.4
80-kilometer population (person-rem)	740	12	2,200 - 5,400	5.6 - 28
Offsite MEI probability of latent cancer fatality	0.000019	3.1×10^{-7}	0.00001 - 0.00005	1.5×10^{-7} - 7.2×10^{-7}
80-kilometer population number of latent cancer fatalities	0.37	0.006	1.1 - 2.7	0.0028 - 0.014

a. MEI = maximally exposed individual.

Table 8-26. Summary of industrial hazard health and safety impacts to facility workers during closure phase.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	320	340 - 420
Lost workday cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved worker		
Total recordable cases of injury and illness	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers		
Total recordable cases of injury and illness	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	350	400 - 600
Lost workday cases	170	190 - 280
Fatalities	0.17	0.19 - 0.28
Noninvolved worker		
Total recordable cases of injury and illness	54	59 - 82
Lost workday cases	26	29 - 40
Fatalities	0.048	0.052 - 0.072
All workers		
Total recordable cases of injury and illness	400	460 - 680
Lost workday cases	200	220 - 320
Fatalities	0.22	0.24 - 0.35

a. Source: Appendix F, Tables F-38 and F-66.

Industrial Hazards to Workers

Table 8-29 summarizes health and safety impacts to workers from industrial hazards common to the workplace for all phases. The calculated health impacts from industrial hazards common to the workplace would be in the range of 2 to 3 fatalities for Inventory Module 1 or 2. Most of the impacts would come from the operations period. Industrial safety impacts for Module 1 or 2 are about 30 to 40 percent greater than those for the Proposed Action.

Radiological Health

Workers. Table 8-30 summarizes radiological doses and health impacts to workers for the Proposed Action and Inventory Module 1 or 2. It lists these impacts as the likelihood of a latent cancer fatality for the maximally exposed individual worker over a 50-year working career, and as the number of latent cancer fatalities that could occur in the population. The calculated values for latent cancer fatalities for repository workers during the construction, operation and monitoring, and closure phases for Module 1 or 2 are in the range of 6 to 8 fatalities for Module 1 or 2. These are higher than those for the Proposed Action (4 to 7 fatalities) and would be about double those from normal workplace industrial hazards (see Table 8-29).

Most of the total worker radiation dose would be from the receipt and handling of spent nuclear fuel during the operation period. Radiation exposure from inhalation of radon-222 and its decay products by exposure to radiation emanating from the subsurface would also be contributors to the total dose. No other activities in the area were identified that could cause cumulative impacts to repository workers.

Table 8-27. Summary of radiological health impacts to workers from all activities during closure phase.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	320	340 - 420
Lost workday cases	150	160 - 200
Fatalities	0.15	0.16 - 0.2
Noninvolved worker		
Total recordable cases of injury and illness	51	53 - 62
Lost workday cases	25	26 - 30
Fatalities	0.045	0.047 - 0.054
All workers		
Total recordable cases of injury and illness	370	390 - 480
Lost workday cases	180	190 - 230
Fatalities	0.2	0.21 - 0.25
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	350	400 - 600
Lost workday cases	170	190 - 280
Fatalities	0.17	0.19 - 0.28
Noninvolved worker		
Total recordable cases of injury and illness	54	59 - 82
Lost workday cases	26	29 - 40
Fatalities	0.048	0.052 - 0.072
All workers		
Total recordable cases of injury and illness	400	460 - 680
Lost workday cases	200	220 - 320
Fatalities	0.22	0.24 - 0.35

a. Source: Appendix F, Tables F-39 and F-67.

Table 8-28. Radiological health impacts to the public from the closure phase.

Impact	Higher-temperature: Total	Higher-temperature: Maximum annual	Lower-temperature: Total	Lower-temperature: Annual
	Proposed Action			
Dose to public				
Offsite MEI[a] (millirem)	3	0.39	4.3 - 9.4	0.55 - 0.85
80-kilometer population (person-rem)	57	7.4	83 - 180	10 - 16
Offsite MEI probability of latent cancer fatality	1.5×10^{-6}	1.9×10^{-7}	2.2×10^{-6} - 4.7×10^{-6}	2.7×10^{-7} - 4.2×10^{-7}
80-kilometer population number of latent cancer fatalities	0.028	0.0037	0.041 - 0.09	0.0052 - 0.0081
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	4.9	0.57	8.5 - 19	0.83 - 1.4
80-kilometer population (person-rem)	95	11	160 - 360	16 - 26
Offsite MEI probability of latent cancer fatality	2.5×10^{-6}	2.9×10^{-7}	4.2 × 10-6 - 9.5×10^{-6}	4.2×10^{-7} - 6.9×10^{-7}
80-kilometer population number of latent cancer fatalities	0.047	0.0055	0.081 - 0.18	0.008 - 0.013

a. MEI = maximally exposed individual.

Public. Table 8-31 summarizes radiological doses and health impacts to the public during all phases for the Proposed Action and Inventory Module 1 or 2. The radiological doses and health impacts would result from exposure of the public to naturally occurring radon-222 and decay products released from the subsurface facilities in ventilation exhaust air. The calculated likelihood for Module 1 or 2 that the maximally exposed individual would experience a latent cancer fatality is less than 0.00005. The

Table 8-29. Summary of industrial hazard health and safety impacts to facility workers during all phases.[a]

Worker group	Operating mode	
	Higher-temperature	Lower-temperature[b]
	Proposed Action	
Involved worker		
Total recordable cases of injury and illness	2,200	2,500 - 3,300
Lost workday cases	1,000	1,200 - 1,500
Fatalities	1.5	1.8 - 2.6
Noninvolved worker		
Total recordable cases of injury and illness	470	500 - 720
Lost workday cases	230	250 - 350
Fatalities	0.45	0.48 - 0.68
All workers		
Total recordable cases of injury and illness	2,700	3,000 - 4,000
Lost workday cases	1,200	1,500 - 1,900
Fatalities	2	2.3 - 3.3
	Inventory Module 1 or 2	
Involved worker		
Total recordable cases of injury and illness	2,900	3,400 - 4,000
Lost workday cases	1,400	1,600 - 1,900
Fatalities	2.1	2.4 - 3.1
Noninvolved worker		
Total recordable cases of injury and illness	640	690 - 830
Lost workday cases	310	340 - 410
Fatalities	0.61	0.65 - 0.78
All workers		
Total recordable cases of injury and illness	3,500	4,100 - 4,800
Lost workday cases	1,700	1,900 - 2,300
Fatalities	2.7	3.1 - 3.9

a. Source: Appendix F, Tables F-40 and F-68.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because the values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

estimated increase in the number of latent cancer fatalities is less than 2 for the exposed population within about 80 kilometers (50 miles) over the period of more than 100 years of repository activities.

For purposes of comparison, the number of latent cancer fatalities calculated from the public for the Yucca Mountain construction, operation and monitoring, and closure phases for Inventory Module 1 or 2 would be less than 0.75. Statistics published by the Centers for Disease Control indicate that during 1998, 24 percent of all deaths in the State of Nevada were attributable to cancer of some type and cause (adapted from DIRS 153066-Murphy 2000, p. 83). Assuming this rate would remain unchanged for the estimated population in 2035 of about 76,000 within 80 kilometers (50 miles) of the Yucca Mountain site, about 18,000 members of this population would be likely to die from cancer-related causes.

As discussed in Section 8.2.2.2.2, the current operations at the Nevada Test Site resulted in a dose to the maximally exposed individual in 1999 of 0.12 millirem. During that same year, the population dose from Nevada Test Site activities was 0.38 person-rem. Conservatively adding the doses from repository activities to Nevada Test Site activities would result in a dose of 2.3 millirem to the maximally exposed individual and 42 person-rem to the population.

As discussed in the introduction to Section 8.2.7, potential radiological doses from past weapons testing at the Nevada Test Site could result in additional impacts to those residents who were present during that

Table 8-30. Summary of radiological health impacts to workers from all activities during all phases.[a]

Worker group	Operating mode: Higher-temperature	Operating mode: Lower-temperature[b]
	Proposed Action	
Involved worker		
Dose to maximally exposed worker (millirem)	18,000	18,000 - 30,000
Probability of latent cancer fatality	0.0072	0.0072 - 0.012
Collective dose (person-rem)	9,800	11,000 - 17,000
Number of latent cancer fatalities	3.9	4.4 - 6.8
Noninvolved worker		
Dose to maximally exposed worker (millirem)	1,800	1,800
Probability of latent cancer fatality	0.00072	0.00072
Collective dose (person-rem)	230	280 - 360
Number of latent cancer fatalities	0.092	0.11 - 0.14
All workers		
Collective dose (person-rem)	10,000	11,000 - 17,000
Number of latent cancer fatalities	4	4.4 - 6.8
	Inventory Module 1 or 2	
Involved worker		
Dose to maximally exposed worker (millirem)	24,000	24,000 - 33,000
Probability of latent cancer fatality	0.0096	0.0096 - 0.013
Collective dose (person-rem)	14,000	16,000 - 20,000
Number of latent cancer fatalities	5.6	6.4 - 8
Noninvolved worker		
Dose to maximally exposed worker (millirem)	2,400	2,400
Probability of latent cancer fatality	0.00096	0.00096
Collective dose (person-rem)	270	330 - 410
Number of latent cancer fatalities	0.11	0.13 - 0.16
All workers		
Collective dose (person-rem)	14,000	16,000 - 20,000
Number of latent cancer fatalities	5.6	6.4 - 8

a. Source: Appendix F, Tables F-41 and F-69.
b. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because the values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.

Table 8-31. Summary of radiological health impacts to the public from all project phases.

Impact	Higher-temperature: Total	Higher-temperature: Maximum annual	Lower-temperature[a]: Total	Lower-temperature[a]: Annual
	Proposed Action			
Dose to public				
Offsite MEI[b] (millirem)	31	0.73	44 - 62	1 - 1.3
80-kilometer population (person-rem)	930	14	1,900 - 3,900	20 - 26
Offsite MEI probability of latent cancer fatality	0.000016	3.7×10^{-7}	0.000022 - 0.000031	5.2×10^{-7} - 6.7×10^{-7}
80-kilometer population number of latent cancer fatalities	0.46	0.0071	0.97 - 2	0.010 - 0.013
	Inventory Module 1 or 2			
Dose to public				
Offsite MEI (millirem)	51	0.94	60 - 110	1.3 - 2.2
80-kilometer population (person-rem)	1,300		3,100 - 6,200	5.6 - 42
Offsite MEI probability of latent cancer fatality	0.000026	4.7×10^{-7}	0.00003 - 0.000057	6.7×10^{-7} - 1.1×10^{-6}
80-kilometer population number of latent cancer fatalities	0.65	0.0091	1.5 - 3.1	0.0028 - 0.021

a. These ranges might differ from simple addition of the minimum and maximum values listed for the constituent phases because the values might not correspond between different phases. For example, a scenario that maximizes impacts during construction could result in minimal impacts during operations.
b. MEI = maximally exposed individual.

timeframe. If the maximally exposed individual is assumed to have also been present during the entire time period in which weapons testing occurred, the maximally exposed individual dose listed in Table 8-31 could be increased by as much as 150 millirem. (These doses have been included in Table 8-60.)

8.2.8 ACCIDENTS

Disposal in the proposed repository of the additional spent nuclear fuel and high-level radioactive waste along with the Greater-Than-Class-C waste and Special-Performance-Assessment-Required waste in Inventory Module 1 or 2 would result in a very small increase in the estimated risk from accidents described in Chapter 4, Section 4.1.8, for the Proposed Action. The potential hazards and postulated accident scenarios identified and evaluated in Chapter 4, Section 4.1.8, would be the same as those for Module 1 or 2 because there would be no change to the basic repository design or operation. The time required for receipt, packaging, and emplacement of the additional waste would extend from 24 to 38 years, but the probability of an accident scenario (likelihood per year) would be essentially unaffected. The accident scenario consequences evaluated for the Proposed Action would bound those that could occur for Inventory Module 1 or 2 because the spent nuclear fuel and high-level radioactive waste, except the Greater-Than-Class-C waste and the Special-Performance-Assessment-Required waste, would be the same. DOE has not determined the final disposition method for Greater-Than-Class-C and Special-Performance-Assessment-Required waste but, based on the characteristics and expected packaging of these wastes (type and quantity of radionuclides; see Appendix A), the accident scenario consequences calculated in Chapter 4, Section 4.1.8 for spent nuclear fuel and high-level radioactive waste would be bounding. Therefore, substantial cumulative accident impacts would be unlikely for Inventory Module 1 or 2.

The analysis of potential external events in Appendix H considered the potential effects on the Yucca Mountain Repository if there was a decision in the future to resume nuclear weapons testing or from a possible vehicle launch or recovery accident at the proposed VentureStar®/Kistler project. An earlier environmental assessment (DIRS 100136-DOE 1986, all) states that DOE could temporarily suspend underground repository activities during a nuclear weapons test to ensure worker safety. The Department has not decided that such a suspension of work activities at the repository would be necessary at the present time; however, as it finalized the design of the proposed repository, the Department could find it necessary to enact worker safety requirements at the repository site if there was a resumption of nuclear weapons testing. As discussed in Section 8.1.2.2, the Kistler aerospace activity is currently on hold.

In addition, the analysis identified no other Federal, non-Federal, or private action that could affect either the occurrence probability or consequences of the accident scenarios evaluated for the Proposed Action or Inventory Modules.

8.2.9 NOISE

The emplacement of Inventory Module 1 or 2 would have noise levels associated with the construction and operation of the repository similar to those for the Proposed Action. An increase in potential noise impacts from Module 1 or 2 would result only from the increased number of shipments to the site. The expected rate of receipt would be about the same as that for the Proposed Action; therefore, the impact would be an extended period (approximately 14 years) that shipping would continue beyond the Proposed Action.

DOE does not expect other Federal, non-Federal, or private actions in the region to add measurable noise impacts to those of the Proposed Action or Inventory Module 1 or 2 because the other activities are some distance from the proposed repository, and it is unlikely that overall increased noise would result.

8.2.10 AESTHETICS

There would be no impacts for Inventory Module 1 or 2 beyond those described in Chapter 4, Section 4.1.10, because the profile of the repository facility would not be different as a result of implementation of Modules 1 or 2. One action that could add to cumulative aesthetics impacts of the region would be the construction and operation of a proposed wind farm (DIRS 154545-DOE 2001, all) on the Nevada Test Site. The locations being considered for the proposed wind farm are located within the areas of Pahute Mesa and the Shoshone Mountains. The areas under consideration are higher in elevation than the surrounding environs. With the addition of the wind turbine to maximum heights of approximately 430 feet above-ground surface these wind turbines may be visible from the west (especially from mountain ranges west of the Nevada Test Site).

8.2.11 UTILITIES, ENERGY, MATERIALS, AND SITE SERVICES

This section discusses potential impacts to utilities, energy, materials, and site services from the construction, operation and monitoring, and closure of the repository for Inventory Module 1 or 2. The scope of the analysis includes electricity use, fossil-fuel and oil and lubricant consumption, and consumption of construction materials. Chapter 4, Section 4.1.11, evaluates special services such as emergency medical support, fire protection, and security and law enforcement, which would not change for Inventory Module 1 or 2. The material in this section parallels Section 4.1.11, which addresses impacts from the Proposed Action. DOE has considered the other actions described in Section 8.1 to evaluate the potential for cumulative impacts on utilities, energy, materials, and site services. Most of the actions have limited information on their potential cumulative impacts, or the available information indicates that there could be no cumulative impacts. However, one action that would potentially have a cumulative impact is the Alternative Energy Generation Facility (Wind Farm) on the Nevada Test Site, which would increase electrical generating capacity for the region by approximately 600 megawatts, which represents less than 15 percent of the peak power (4,300 megawatts) distributed by Nevada Power in 2000, as described in Chapter 3, Section 3.1.11.2.

To determine the potential impacts of Inventory Module 1 or 2, DOE evaluated the projected uses of electricity, fuel, oils and lubricants and construction materials for each repository phase and compared them to those for the Proposed Action. The following paragraphs describe these evaluations.

Construction

As in the Proposed Action, the major impact during the construction phase for Inventory Module 1 or 2 would be the estimated demand for electric power. The peak demand for electricity for the Proposed Action would be 25 megawatts during construction (Table 8-32). During the construction required for Module 1 or 2, the peak demand for electricity would be about the same (25 megawatts). The tunnel boring machines would account for more than half of the demand for electricity during the 5-year construction phase, but power would also be required to operate ventilation equipment and to support the construction of surface facilities. As for the Proposed Action, the existing electric transmission and distribution system at the Nevada Test Site could not support this increased demand. DOE is evaluating modifications to the site electrical system, as discussed in Chapter 4, Section 4.1.11.

The use of electricity for the higher-temperature operating mode for Inventory Module 1 or 2 would be about 150,000 megawatt-hours during the construction phase, which is about the same as for the Proposed Action (see Table 8-33). For the lower-temperature operating mode the electricity usage ranges from 190,000 to 210,000 megawatt-hours, which is the same as for the Proposed Action. The similarity in numbers between the Proposed Action and the Inventory Modules is due to the similar length of time for construction activities.

Table 8-32. Peak electric power demand (megawatts).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	25	25
Operation and monitoring		
Operation	47	40 - 54
Monitoring	8	7.8 - 15
Closure	10	10 - 18
Maximum	47	40 - 54
Inventory Module 1 or 2		
Construction	25	25
Operation and monitoring		
Operation	53	44 - 54
Monitoring	11	11 - 15
Closure	14	10 - 18
Maximum	53	44 - 54

Table 8-33. Electricity use (1,000 megawatt-hours).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	150	190 - 210
Operation and monitoring		
Operation	5,200	5,300 - 9,200
Monitoring	4,800	9,700 - 29,000
Closure	720	790 - 1,300
Totals	***11,000***	***16,000 - 36,000***
Inventory Module 1 or 2		
Construction	150	190 - 200
Operation and monitoring		
Operation	8,200	7,700 - 9,700
Monitoring	6,000	11,000 - 39,000
Closure	1,100	1,300 - 1,600
Totals	***15,000***	***21,000 - 50,000***

The use of liquid fossil fuel during the construction phase would include diesel fuel and fuel oil. The estimated liquid fuel use would be 5.5 to 6 million liters (1.5 to 1.6 million gallons) which would be about the same as for the Proposed Action (see Table 8-34). About 2.6 to 3.5 million liters of oils (primarily hydraulic oil) and lubricants would also be used to support construction as shown in Table 8-35. The usage rate should be well within the regional supply capacity and, therefore, would not result in substantial impacts.

The primary materials needed to support construction would be concrete, steel, and copper. Concrete would be used for liners in the main drifts and ventilation shafts. Concrete also would be used in the construction of the surface facilities. The quantity of concrete required for the surface facilities and initial emplacement drift construction would be about 420,000 to 500,000 cubic meters (550,000 to 650,000 cubic yards). Cement (see Table 8-36) would come from regional suppliers. Sand and gravel needs would be met from materials excavated from the repository or hauled to the repository by local/regional suppliers. As much as 120,000 metric tons (132,000 tons) of steel for a variety of uses including rebar, piping, vent ducts, and track, and 230 metric tons (250 tons) of copper for electrical cable also would be required. These quantities would not be likely to affect the regional supply capacity.

Table 8-34. Fossil-fuel use (million liters).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	5.5	5.5 - 6.0
Operation and monitoring		
Operation	360	360 - 500
Monitoring	2.3	2.6 - 13
Closure	5.2	5.1 - 6.6
Totals	***370***	***380 - 510***
Inventory Module 1 or 2		
Construction	5.4	5.5 - 6.1
Operation and monitoring		
Operation	550	550 - 600
Monitoring	2.1	7 - 22
Closure	7.4	6.1 - 6.9
Totals	***560***	***570 - 620***

Table 8-35. Oils and lubricants (million liters).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	2.6	3.1 - 3.5
Operation and monitoring		
Operation	8.5	9.8 - 18
Monitoring	9	13 - 53
Closure	1.7	1.8 - 3
Totals	***22***	***33 - 71***
Inventory Module 1 or 2		
Construction	2.6	3.1 - 3.5
Operation and monitoring		
Operation	13	16 - 27
Monitoring	9.9	23 - 110
Closure	3.8	2.9 - 3.2
Totals	***30***	***56 - 140***

Table 8-36. Cement use (1,000 metric tons).

Phase	Operating mode	
	Higher-temperature	Lower-temperature
Proposed Action		
Construction	160	190
Operation and monitoring		
Operation	100	150 - 340
Monitoring	0	0
Closure	1.2	1.2 - 1.9
Totals	***250***	***310 - 530***
Inventory Module 1 or 2		
Construction	160	160 - 190
Operation and monitoring		
Operation	260	290 - 890
Monitoring	0	0
Closure	1.9	1.9 - 2.0
Totals	***420***	***480 - 1,100***

Operation and Monitoring

The event that would indicate the start of the operation and monitoring phase would be the beginning of emplacement of spent nuclear fuel and high-level radioactive waste. During this phase the construction of emplacement drifts would continue in parallel with emplacement activities at about the same rate as during the construction phase. As a result, the peak electric power demand would increase to between about 44 and 54 megawatts. The maximum value of 54 megawatts would be about the same as that for the Proposed Action. As was the case for the Proposed Action, DOE would have to upgrade or revise the transmission and distribution system on the Nevada Test Site to meet this demand. However, the upgrade or revision for the Proposed Action would accommodate the similar increase for Inventory Module 1 or 2.

The demand for electricity for Inventory Module 1 or 2 would be well within the regional capacity for power generation. Nevada Power Company, for example, plans to maintain a reserve capacity of about 12 percent. For the beginning of the operation and monitoring phase in 2010, Nevada Power projects a net peak load of about 6,000 megawatts and plans a reserve of about 710 megawatts (DIRS 103413-NPC 1997, Figure 4, p. 9). The repository peak demand of 54 megawatts would be less than 1 percent of the Nevada Power Company planned capacity and about 8 percent of planned reserves. The repository would not affect the regional availability of electric power to any extent.

Fossil-fuel use during the operation and monitoring phase would be for onsite vehicles and for heating. It should range between 360 and 500 million liters (100 and 130 million gallons) during repository operations. The corresponding use of oils and lubricants would be between 23 and 130 million liters (6 and 34 million gallons). The annual usage rates for fuels would be highest during the first half of the operation and monitoring phase (emplacement and continued construction of drifts) and would decrease substantially during the monitoring period (see Table 8-34). The projected annual usage rates of liquid petroleum products would be higher than those for the Proposed Action but would still be within the regional supply capacity.

Additional construction materials would be required to support the continued construction of subsurface facilities for Inventory Module 1 or 2. About 660,000 cubic meters (860,000 cubic yards) of concrete would be required for the flexible design, higher-temperature repository operating mode, and 730,000 to 2,300,000 cubic meters (950,000 to 3,000,000 cubic yards) would be required for the lower-temperature repository operating mode (see Table 8-37). Corresponding amounts of cement that would be obtained regionally are shown in Table 8-36.

Table 8-37. Concrete use (1,000 cubic meters).

Phase	Operating mode: Higher-temperature	Operating mode: Lower-temperature
Proposed Action		
Construction	420	490 - 500
Operation and monitoring		
Operation	240	350 - 880
Monitoring	0	0
Closure	3	3 - 5
Totals	***670***	***850 - 1,400***
Inventory Module 1 or 2		
Construction	420	430 - 490
Operation and monitoring		
Operation	660	730 - 2,300
Monitoring	0	0
Closure	5	4 - 5
Totals	***1,100***	***1,200 - 2,800***

The requirement for steel would be between 120,000 and 360,000 metric tons (130,000 and 390,000 tons), and for copper it would be about 200 and 1,100 metric tons (220 and 1,200 tons) (see Tables 8-38 and 8-39). These quantities, while above the Proposed Action, would be unlikely to affect the regional supply capacity because the annual usage rate would be only slightly higher than that for the Proposed Action.

Table 8-38. Steel use (1,000 metric tons).

	Operating mode	
Phase	Higher-temperature	Lower-temperature
Proposed Action		
Construction	100	120
Operation and monitoring		
Operation	62	150 - 180
Monitoring	0	0
Closure	0.03	0.04
Totals	***160***	***270 - 300***
Inventory Module 1 or 2		
Construction	100	100 - 120
Operation and monitoring		
Operation	120	190 - 360
Monitoring	0	0
Closure	0.04	0.04 - 0.07
Totals	***230***	***290 - 480***

Table 8-39. Copper use (1,000 metric tons).

	Operating mode	
Phase	Higher-temperature	Lower-temperature
Proposed Action		
Construction	0.20	0.23
Operation and monitoring		
Operation	0.08	0.24 - 0.6
Monitoring	0	0
Closure	0	0
Totals	***0.30***	***0.50 - 0.86***
Inventory Module 1 or 2		
Construction	0.20	0.16 - 0.23
Operation and monitoring		
Operation	0.20	0.3 - 1.1
Monitoring	0	0
Closure	0	0
Totals	***0.4***	***0.46 - 1.3***

Closure

The peak electric power required during the closure phase for Inventory Module 1 or 2 would be only slightly higher than that for the Proposed Action and would be less than 20 megawatts for all operating modes. This would be much less than the peak levels predicted for the earlier phases, so impacts would be small.

Fossil-fuel use would be between 6.1 million and 7.4 million liters (1.6 million and 2.0 million gallons). A small amount of concrete and steel would be used for closure. An estimated maximum of 5,000 cubic meters (6,500 cubic yards) of concrete would be required for any operating mode. Similarly, an estimated maximum 70 metric tons (77 tons) of steel would be required for closure. The fossil-fuel and material quantities required for closure would not be large and would not result in substantial impacts.

8.2.12 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

8.2.12.1 Inventory Module 1 or 2 Impacts

Activities for the emplacement of Inventory Module 1 or 2 would generate waste totals beyond the quantities estimated for the Proposed Action (see Chapter 4, Section 4.1.12). The generated waste types and the treatment and disposal of each waste type would be the same as those described for the Proposed Action. The quantities of generated waste are primarily affected by the increase in the amount of spent nuclear fuel and waste emplaced and the subsequent longer operations and monitoring and closure phases. (Table 8-3 lists the difference in time sequences.) Table 4-40 presents the waste types and quantities generated from activities during the construction phase. This table applies to both the Proposed Action and the Inventory Modules because the timeframe and actions are the same during this phase. Table 8-40 lists the waste quantities generated for Inventory Modules 1 and 2 for the operation and monitoring phase. Table 8-41 lists the waste quantities generated for Inventory Modules 1 and 2 for the closure phase.

Table 8-40. Estimated operation and monitoring phase waste quantities.[a]

	Operating mode	
Waste type	Higher-temperature	Lower-temperature
	Inventory Module 1	
Low-level radioactive (cubic meters)a	110,000	110,000 - 230,000
Hazardous (cubic meters)	10,000	9,200 - 16,000
	Inventory Module 2	
Low-level radioactive (cubic meters)	130,000	130,000 - 270,000
Hazardous (cubic meters)	12,000	11,000 - 20,000
	Inventory Module 1 or 2	
Sanitary and industrial solid (cubic meters)	110,000	120,000 - 170,000
Sanitary sewage[b] (million liters)	2,500	3,000 - 3,900
Industrial wastewater (million liters)	1,400	1,400 - 2,200

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. To convert liters to gallons, multiply by 0.26418.

Table 8-41. Estimated closure phase waste quantities.[a]

	Inventory Module 1 or 2	
Waste type	Higher-temperature	Lower-temperature
Low-level radioactive (cubic meters)[b]	3,500	3,200 - 7,100
Hazardous (cubic meters)	1,200	1,100 - 1,800
Sanitary and industrial solid (cubic meters)	10,000	14,000 - 18,000
Sanitary sewage (million liters)[c]	180	240 - 410
Industrial wastewater (million liters)	84	110 - 160
Demolition debris (cubic meters)	220,000	220,000 - 440,000

a. To convert cubic meters to cubic feet, multiply by 35.314.
b. Module 1 is 7,000 cubic meters.
c. To convert liters to gallons, multiply by 0.26418.

Sanitary and industrial solid waste, sanitary sewage, and industrial wastewater would be disposed of in facilities at the repository site. These facilities would be designed to accommodate the additional waste from Inventory Module 1 or 2. However, DOE could use existing Nevada Test Site landfills to dispose of nonrecyclable construction and demolition debris and sanitary and industrial solid waste. If Nevada Test Site landfills were used, about 360,000 cubic meters (13 million cubic feet) for the higher-temperature operating mode and 640,000 cubic meters (23 million cubic feet) under the lower-temperature operating mode would be disposed of from construction through closure. Disposal of the Proposed Action waste quantities would require the Nevada Test Site landfills to operate past their projected operating lives and to expand as needed (Chapter 4, Section 4.1.12.2). Disposal of the larger waste quantities under Inventory Module 1 or 2 would require the availability of additional disposal capacity in future landfill expansions.

Impacts from the treatment and disposal of hazardous waste off the site would be the same for the Proposed Action and Inventory Module 1 or 2. At present, commercial facilities are available for hazardous waste treatment and disposal, and DOE expects similar facilities to be available until the closure of the repository. The National Capacity Assessment Report (DIRS 103245-EPA 1996, pp. 32, 33, 36, 46, 47, and 50) indicates that the estimated 20-year (1993 to 2013) available capacity for incineration of solids and liquids at permitted treatment facilities in the western states is about 7 times more than the demand for these services. Moreover, the report indicates that the estimated landfill capacity for hazardous waste disposal is about 50 times the demand. Given the current outlook for the capacity versus demand for hazardous waste treatment and disposal, the treatment and disposal of repository-generated hazardous waste would not present a large cumulative impact.

The Nevada Test Site has an estimated total disposal capacity of 3.7 million cubic meters (130 million cubic feet). The DOE analysis of demand for low-level radioactive waste disposal at the Nevada Test Site through 2070 projects a need for about 1.1 million cubic meters (39 million cubic feet or 30 percent) of the total disposal capacity (DIRS 155856-DOE 2000, Table 4-1). The reserve capacity at the Nevada Test Site is about 2.6 million cubic meters (92 million cubic feet). The disposal of repository-generated waste would require about 5 percent of the reserve capacity for the higher-temperature operating mode and about 5 percent to 9 percent for the lower-temperature operating mode.

Even under the Final Waste Management Programmatic Environmental Impact Statement's (DIRS 101816-DOE 1997, pp. 7-23 and I-39) regional disposal concept, the disposal of repository-generated low-level radioactive waste under the Proposed Action and Inventory Module 1 or 2, cumulatively with other DOE waste generators, would use less than 20 percent of the Nevada Test Site's reserve disposal capacity.

The emplacement of Inventory Module 1 or 2 would require the same types and annual quantities of hazardous materials as the Proposed Action, as described in Chapter 4, Section 4.1.12.3. These materials would be used for the additional years associated with the emplacement of the module inventory. As with the Proposed Action, no cumulative impact would be likely from the procurement and use of hazardous materials at the repository.

8.2.12.2 Cumulative Impacts from Inventory Module 1 or 2 and Other Federal, Non-Federal, and Private Actions

Waste operations at the Nevada Test Site (disposing of Nevada Test Site-generated waste and accepting waste from other sites in accordance with decisions from the Waste Management Programmatic EIS) could present a cumulative impact. Section 8.2.12.1 discusses the impact on Test Site facilities from disposal of repository waste and waste that is already projected to be disposed of at the Test Site.

If Nevada Test Site landfills are used to dispose of nonrecyclable construction and demolition debris and sanitary and industrial waste, the landfills would be required to operate past their projected operating lives and to expand as needed (the degree of expansion would depend on how much waste was disposed of at the repository facilities).

Low-level waste capacity at the Nevada Test Site is sufficient to accommodate the repository-generated waste and the projected volume of 1.1 million cubic meters of waste from the Test Site, although the facility might have to use some of its reserve capacity to meet the combined need.

8.2.13 ENVIRONMENTAL JUSTICE

As discussed in Chapter 4, Section 4.1.13, the environmental justice analysis brings together the results of all resource and feature analyses to determine (1) if an activity would have substantial environmental impacts and (2) if those substantial impacts would have disproportionately high and adverse human health or environmental effects on minority or low-income populations. DOE determined that cumulative impacts from Inventory Module 1 or 2 along with those expected from other Federal, non-Federal, and private actions would not produce cumulative adverse impacts to any surrounding populations, which would include minority and low-income populations. Evaluation of subsistence lifestyles and cultural values has confirmed that these factors would not change the conclusion that the absence of high and adverse impacts for the general population means there would be no disproportionately high and adverse impacts on minority or low-income communities. No substantial impacts were identified; therefore, cumulative impacts from Inventory Module 1 or 2 and other Federal, non-Federal, and private actions would not cause environmental justice concerns.

DOE recognizes that Native American people living in areas near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on access to the site. Chapter 4, Section 4.1.3.4, discusses these views and beliefs.

8.3 Cumulative Long-Term Impacts in the Proposed Yucca Mountain Repository Vicinity

This section describes results from the long-term cumulative impact analysis that DOE conducted for Inventory Modules 1 and 2 (Section 8.3.1) and for past, present, and reasonably foreseeable future actions at the Nevada Test Site, and past actions at the Beatty low-level radioactive waste site (Section 8.3.2).

8.3.1 INVENTORY MODULE 1 OR 2 IMPACTS

The analysis of long-term performance for Inventory Modules 1 and 2 used the same methodology described in Chapter 5 and Appendix I for the Proposed Action to estimate potential human health impacts from radioactive and chemically toxic material releases through waterborne and airborne pathways. Section 8.3.1.1 presents the radioactive and chemically toxic material source terms for Inventory Modules 1 and 2, and Sections 8.3.1.2 and 8.3.1.3 present the results of the analysis for Inventory Modules 1 and 2, respectively.

In addition to long-term human health impacts from radioactive and chemically toxic material releases, the other potential long-term impact identified following repository closure involve biological resources. Though the surface area affected by heat rise would be larger for Inventory Module 1 or 2, the amount of heat per unit area would be constant for a given repository operating mode (lower- or higher-temperature), and, therefore, the small ground surface temperature increase would be the same. Thus, long-term biological effects of Module 1 or 2 from heat generated by waste packages that would potentially raise ground surface temperatures would be the same as those described in Chapter 5, Section 5.9 for the Proposed Action.

8.3.1.1 Radioactive and Chemically Toxic Material Source Terms for Inventory Modules 1 and 2

For calculations of long-term performance impacts, the radioactive material inventory of individual waste packages for commercial spent nuclear fuel, high-level radioactive waste, and DOE spent nuclear fuel under Inventory Modules 1 and 2 would be identical to the radioactive material inventory under the

8.2.13 ENVIRONMENTAL JUSTICE

As discussed in Chapter 4, Section 4.1.13, the environmental justice analysis brings together the results of all resource and feature analyses to determine (1) if an activity would have substantial environmental impacts and (2) if those substantial impacts would have disproportionately high and adverse human health or environmental effects on minority or low-income populations. DOE determined that cumulative impacts from Inventory Module 1 or 2 along with those expected from other Federal, non-Federal, and private actions would not produce cumulative adverse impacts to any surrounding populations, which would include minority and low-income populations. Evaluation of subsistence lifestyles and cultural values has confirmed that these factors would not change the conclusion that the absence of high and adverse impacts for the general population means there would be no disproportionately high and adverse impacts on minority or low-income communities. No substantial impacts were identified; therefore, cumulative impacts from Inventory Module 1 or 2 and other Federal, non-Federal, and private actions would not cause environmental justice concerns.

DOE recognizes that Native American people living in areas near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the Proposed Action, and that the implementation of the Proposed Action would continue restrictions on access to the site. Chapter 4, Section 4.1.3.4, discusses these views and beliefs.

8.3 Cumulative Long-Term Impacts in the Proposed Yucca Mountain Repository Vicinity

This section describes results from the long-term cumulative impact analysis that DOE conducted for Inventory Modules 1 and 2 (Section 8.3.1) and for past, present, and reasonably foreseeable future actions at the Nevada Test Site, and past actions at the Beatty low-level radioactive waste site (Section 8.3.2).

8.3.1 INVENTORY MODULE 1 OR 2 IMPACTS

The analysis of long-term performance for Inventory Modules 1 and 2 used the same methodology described in Chapter 5 and Appendix I for the Proposed Action to estimate potential human health impacts from radioactive and chemically toxic material releases through waterborne and airborne pathways. Section 8.3.1.1 presents the radioactive and chemically toxic material source terms for Inventory Modules 1 and 2, and Sections 8.3.1.2 and 8.3.1.3 present the results of the analysis for Inventory Modules 1 and 2, respectively.

In addition to long-term human health impacts from radioactive and chemically toxic material releases, the other potential long-term impact identified following repository closure involve biological resources. Though the surface area affected by heat rise would be larger for Inventory Module 1 or 2, the amount of heat per unit area would be constant for a given repository operating mode (lower- or higher-temperature), and, therefore, the small ground surface temperature increase would be the same. Thus, long-term biological effects of Module 1 or 2 from heat generated by waste packages that would potentially raise ground surface temperatures would be the same as those described in Chapter 5, Section 5.9 for the Proposed Action.

8.3.1.1 Radioactive and Chemically Toxic Material Source Terms for Inventory Modules 1 and 2

For calculations of long-term performance impacts, the radioactive material inventory of individual waste packages for commercial spent nuclear fuel, high-level radioactive waste, and DOE spent nuclear fuel under Inventory Modules 1 and 2 would be identical to the radioactive material inventory under the

Proposed Action for the same waste categories. Inventory Module 2 includes an additional waste category for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. This category includes a different category of waste package with its own radioactive material inventory. This waste was simulated with 601 idealized waste packages. The inventory used for each modeled waste package is an averaged radioactive material inventory of each waste category (commercial spent nuclear fuel, DOE spent nuclear fuel, high-level radioactive waste, and Greater-Than-Class-C and Special-Performance-Assessment-Required wastes). More waste packages would be used for Inventory Modules 1 and 2 than for the Proposed Action to accommodate the expanded inventories. Table 8-42 lists the number of waste packages used in the analysis of long-term performance calculations for the Proposed Action and Modules 1 and 2.

Table 8-42. Number of idealized waste packages used in analysis of long-term performance calculations.[a]

Modeled inventory	Commercial SNF[b]	Codisposal (DOE SNF and HLW[c])	GTCC and SPAR[d]	Total
Proposed Action	7,860	3,910	0	11,770
Inventory Module 1	11,754	4,877	0	16,631
Inventory Module 2	11,754	4,877	601	17,232

a. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in the idealized waste packages, the actual number of waste packages emplaced in the proposed repository would be different.

b. SNF = spent nuclear fuel.

c. HLW = high-level radioactive waste.

d. GTCC = Greater-Than-Class-C; SPAR = Special-Performance-Assessment-Required.

IDEALIZED WASTE PACKAGES

The number of waste packages used in the performance assessment simulations do not exactly match the number of actual waste packages specified in DIRS 150558-CRWMS M&O (2000, Section 6.2).

The TSPA model uses two types of *idealized waste packages* (commercial spent nuclear fuel package and codisposal package), representing the averaged inventory of all the actual waste packages used for a particular waste category.

While the number of idealized waste packages varies from the number of actual waste packages in DIRS 150558-CRWMS M&O (2000, Section 6.2), the total radionuclide inventory represented by all of the idealized waste packages collectively is representative of the total inventory, for the radionuclides analyzed, given in Appendix A of this EIS for the purposes of analysis and long-term performance. *The abstracted inventory is designed to be representative for purposes of analysis of long-term performance and cannot necessarily be used for any other analysis, nor can it be directly compared to any other abstracted inventory used for other analyses in this EIS.*

As listed in Table 8-42, Inventory Module 2 differs from Inventory Module 1 only by the addition of 601 Greater-than-Class-C and Special-Performance-Assessment-Required idealized waste packages. Table 8-43 lists the inventory of the Greater-than-Class-C and Special-Performance-Assessment-Required waste packages under Inventory Module 2.

A screening analysis documented in Appendix I, Section I.6.1, showed that the only chemical materials of concern for the 10,000-year analysis period were those that would be released as the external waste package Alloy-22 layer and the waste package support pallet materials corroded. This is because most waste packages would be intact for more than 10,000 years after closure (the results of the analysis of

Table 8-43. Abstracted inventory (grams) of radionuclides passing the screening analysis in each idealized waste package for Greater-Than-Class-C and Special-Performance-Assessment-Required wastes under Inventory Module 2.[a]

Isotope	Inventory
Actinium-227	0
Americium-241	40
Americium-243	0.00151
Carbon-14	28.9
Cesium-137	771
Iodine-129	0.000705
Nickel-63	0
Neptunium-237	0
Protactinium-231	0
Lead-210	0
Plutnium-238	1.56
Plutonium-239	2,860
Plutonium-240	0.0123
Plutonium-241	0.0207
Plutonium-242	0.00614
Radium-226	0.0504
Radium-228	0
Strontium-90	0.82
Technetium-99	568
Thorium-229	0
Thorium-230	0
Thorium-231	0
Uranium-232	0.00000287
Uranium-233	0.00419
Uranium-234	0
Uranium-235	0
Uranium-236	0

a. The idealized waste packages in the simulation (model) are based on the inventory abstraction in Appendix I, Section I.3. While the total inventory is represented by the material in idealized waste packages, the actual number of waste packages emplaced in the proposed repository would be different.

long-term performance for radionuclides described in Appendix I, Section I.5, show that, at most, only three waste packages would be breached before 10,000 years, due to improper heat treatment, under the Proposed Action). Therefore, accounting for the quantities of materials in the engineered barrier system, but not in the waste packages, and accounting for toxicity to humans, the only chemical materials of concern would be chromium, nickel, molybdenum, and vanadium. The inventories of these chemical materials in the engineered barrier system for the Proposed Action and Inventory Modules 1 and 2 are listed in Table 8-44. These are essentially the only inventories available for mobilization and transport within 10,000 years after closure; the inventories of chemical materials in the waste packages would not begin to degrade until waste package failure. Further information on the inventory of chemical materials of concern is provided in Appendix I, Section I.3.

The only radionuclide that would have a relatively large inventory and a potential for gas transport is carbon-14. Iodine-129 can exist in a gas phase, but it is highly soluble and, therefore, would be likely to dissolve in groundwater rather than migrate as a gas. Radon-222 is a gas, but would decay to a solid isotope before escaping from the repository region (see Appendix I, Section I.7.3). After the carbon-14 escaped from the waste package, it could flow through the fractured and porous rock in the form of carbon dioxide. About 2 percent of the carbon-14 in commercial spent nuclear fuel is in gas in the space (or gap) between the fuel and the cladding around the fuel (DIRS 103446-Oversby 1987, p. 92). There are 1.37 grams of carbon-14 in an abstracted commercial spent nuclear fuel waste package (see Appendix I, Table I-5). This represents 6.11 curies per waste package. Since 2 percent of the total is gaseous, the gaseous inventory consists of 0.122 curie of carbon-14 per commercial spent nuclear fuel waste package. There would be additional carbon-14 activity associated with Inventory Module 2, in relation to Module 1, resulting from neutron irradiation of the core shroud metal. The carbon-14 would be unlikely to be present as gaseous carbon dioxide that could be released to the environment and is therefore not included in Table 8-45.

Table 8-44. Total quantities of waterborne chemicals of concern in the engineered barrier system under the Proposed Action and Inventory Modules 1 and 2 (kilograms).[a,b]

Modeled inventory	Chromium	Molybdenum	Nickel	Vanadium
Proposed Action	23,735,000	17,307,000	60,797,000	377,600
Inventory Module 1	34,695,000	25,301,000	88,879,000	552,000
Inventory Module 2	34,951,000	25,490,000	89,545,000	556,000

a. To convert kilograms to pounds, multiply by 2.2046.
b. See screening analysis in Appendix I, Section I.3.2.

Table 8-45. Total **gaseous** carbon-14 in the repository from commercial spent nuclear fuel for the Proposed Action and Inventory Modules 1 and 2 (curies).

Modeled inventory	Quantity[a]
Proposed Action	959
Inventory Module 1	1,430
Inventory Module 2	1,430

a. Based on 0.122 curies of carbon-14 per commercial spent nuclear fuel waste package.

8.3.1.2 Impacts for Inventory Module 1

The human-health impacts from Inventory Module 1 for radioactive materials and chemically toxic materials are discussed in this section.

8.3.1.2.1 *Waterborne Radioactive Material Impacts*

The DOE used the modeling methods described for the Proposed Action in Chapter 5 (and in greater detail in Appendix I) to calculate the impacts both for an individual and the local population resulting from groundwater releases of radioactive material for 10,000 years and 1 million years following repository closure for Inventory Module 1.

8.3.1.2.1.1 Higher-Temperature Operating Mode. Table 8-46 lists the estimated impacts for an individual for the higher-temperature operating mode under the Proposed Action and Inventory Module 1. The peak annual individual dose for the first 10,000 years shows slightly higher values for the mean and 95th percentile of the Proposed Action than for Module 1. Because Module 1 has a higher inventory, this would seem like an incorrect trend. However, note that in the first 10,000 years releases are dominated by at most about 3 waste package failures due to a manufacturing defect (improper heat treatment). Thus, the release is essentially insensitive to inventory and the differences in Table 8-46 between the Proposed Action and Module 1 are merely the result of slightly different statistical outcomes in the 300 simulations.

Table 8-46. Impacts for an individual from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

		Mean			95th-percentile		
Modeled inventory	Individual	Peak annual individual dose (millirem)	Time of peak (years)	Probability of a LCF[a]	Peak annual individual dose (millirem)	Time of peak (years)	Probability of a LCF[a]
Proposed Action	At RMEI location[b]	0.00002[c]	4,900	6×10^{-10}	0.0001[d]	4,900	4×10^{-9}
	At 30 kilometers[e]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
	At discharge location[h]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
Inventory Module 1	At RMEI location[b]	0.00003[c]	4,900	1×10^{-9}	0.002[d]	4,100	6×10^{-9}
	At 30 kilometers[d]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0
	At discharge location[h]	~0[f]	NC[g]	~0	~0[f]	NC[g]	~0

a. LCF = latent cancer fatality; incremental lifetime (70 years) risk of contracting a fatal cancer, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).
b. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository. The maximum allowable peak of the mean annual individual dose for 10,000 years at this distance is 15 millirem.
c. Based on 300 simulations of total system performance, using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. To convert kilometers to miles, multiply by 0.62137.
f. Values would be lower than the small values computed for the RMEI location.
g. NC = not calculated (peak time would be greater than time given for the RMEI location).
h. 60 kilometers (37 miles) at Franklin Lake Playa.

Table 8-47 lists the impacts to the population during the first 10,000 years after repository closure for both the Proposed Action and Inventory Module 1 for the higher-temperature operating mode. These impacts were calculated on the same population basis used for the Proposed Action calculations presented in Chapter 5, that is a population size was based on the projected population numbers for 2035 in Figure 3-25 in Chapter 3. For these calculations, the analysis assumed that no contaminated groundwater

Table 8-47. Population impacts from groundwater releases of radionuclides during 10,000 years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.[a]

Modeled inventory	Case	Mean: Population dose (person-rem)	Mean: Population LCFs[b]	95th-percentile: Population dose (person-rem)	95th-percentile: Population LCFs[b]
Proposed Action	Peak 70-year lifetime	0.006	0.000003	0.04	0.00002
	Integrated over 10,000 years	0.5	0.0002	0.6	0.0003
Inventory Module 1	Peak 70-year lifetime	0.01	0.000005	0.06	0.00003
	Integrated over 10,000 years	0.7	0.0003	0.8	0.0004

a. Based on 300 simulations of total system performance for each location, using random samples of uncertain parameters.
b. LCF = latent cancer fatality; expected number of cancer fatalities for populations, assuming a risk of 0.0005 latent cancer fatality per rem for members of the public (DIRS 101856-NCRP 1993, p. 31).

would reach populations in any regions to the north of Yucca Mountain. Therefore, populations in the sectors north of the due east and due west sectors were not considered to be exposed.

- 47 people would be exposed at the Reasonably Maximally Exposed Individual (RMEI) location [approximately 18 kilometers (11 miles)] downgradient from the repository [includes sectors from 12 to 28 kilometers (7 to 27 miles)].

- 4,200 people would be exposed at about 30 kilometers (19 miles) downgradient from the potential repository [includes sectors from 28 to 44 kilometers (17 to 27 miles)].

- 69,500 people would be exposed at the discharge location, about 60 kilometers (37 miles) downgradient of the potential repository [includes sectors from 44 to 80 kilometers (27 to 50 miles)].

Thus, approximately 74,000 people would be exposed to contaminated groundwater. This stylized population dose analysis assumed that people would continue to live in the locations being used at present. This assumption is consistent with the recommendation made by the National Academy of Sciences (DIRS 100018-National Research Council 1995, all) because it is impossible to make accurate predictions of future lifestyles and residence locations far into the future.

The population impacts would be greater than the impacts for the Proposed Action under the higher-temperature operating mode. For example, the population dose in the 70-year period of maximum impacts would be about 25 percent greater for Module 1 than for the Proposed Action at the mean level and the same 70-year period.

The values in Table 8-47 include a scaling factor for water use. The performance assessment transport model calculated the annual individual dose assuming the radionuclides dissolved in water that flowed through the unsaturated zone of Yucca Mountain would mix in an average of 2.4 million cubic meters (1,940 acre-feet) (DIRS 155950-BSC 2001, p. 13-42) per year in the saturated zone aquifer. This compares to an annual water use in the Amargosa Valley of about 17.1 million cubic meters (13,900 acre-feet) (DIRS 155950-BSC 2001, p. 13-42). The analysis diluted the concentration of the nuclides in the 2.4 million cubic meters of water throughout the 17.1 million cubic meters of water prior to calculating the population dose.

Table 8-48 lists the peak annual individual dose and time of peak for 1 million years after repository closure for both Inventory Module 1 and the Proposed Action for the higher-temperature operating mode. The impacts would follow the same pattern as those for the first 10,000 years after repository closure listed in Table 8-47, with the impacts for Module 1 about 60 percent greater than those for the Proposed Action.

Table 8-48. Impacts to an individual from groundwater releases of radionuclides for 1 million years after repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

		Mean		95th-Percentile	
Modeled inventory	Individual	Peak annual individual dose (millirem)	Time of peak (years)	Peak annual individual dose (millirem)	Time of peak (years)
Proposed Action	At RMEI location[a]	150[b]	480,000	620[c]	410,000
	At 30 kilometers[d]	100[e]	NC[f]	420[e]	NC[f]
	At discharge location[g]	59[e]	NC[f]	240[e]	NC[f]
Inventory Module 1	At RMEI location[a]	240[b]	480,000	980[c]	480,000
	At 30 kilometers[d]	160[e]	NC[f]	660[e]	NC[f]
	At discharge location[g]	90[e]	NC[f]	450[e]	NC[f]

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository.
b. Based on 300 simulations of total system performance for each location, using random samples of uncertain parameters.
c. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
d. To convert kilometers to miles, multiply by 0.62137.
e. Estimated using scale factors as described in Chapter 5, Section 5.4.1.
f. NC = not calculated (peak time would be greater than time given for the RMEI location).
g. 60 kilometers (37 miles) at Franklin Lake Playa.

WHY ARE THE MEAN IMPACTS SOMETIMES HIGHER THAN THE 95TH-PERCENTILE IMPACTS?

The *mean* impact is the arithmetic average of the 300 impact results from simulations of total-system performance. The mean is not the same as the 50th-percentile value (the 50th-percentile value is called the *median*) if the distribution is *skewed*.

The performance results reported in this EIS come from highly skewed distributions. In this context, *skewed* indicates that there are a few impact estimates that are much larger than the rest of the impacts. When a large value is added to a group of small values, the large value dominates the calculation of the mean. The simulations reported in this EIS have mean impacts that are occasionally above the 90th-percentile and occasionally above the 95th percentile.

With respect to groundwater protection standards set forth in 40 CFR Part 197.30, both the mean and the 95th percentile estimated levels during the 10,000-year regulatory period are hundreds of thousands of times less than the regulatory limits (see Table 8-49) for both the Proposed Action and Inventory Module 1.

8.3.1.2.1.2 Lower-Temperature Operating Mode. Impacts were not calculated for the lower-temperature operating mode under Inventory Module 1 or 2 because of the lack of differentiation between higher-temperature and lower-temperature operating modes under the Proposed Action (see Chapter 5). Comparison of the mean individual dose history at the RMEI location for the lower- and higher-temperature operating modes is shown in Figure 8-4. For the Proposed Action, the individual dose for the lower-temperature operating mode at a given location would be about the same as that for the higher-temperature operating mode, with the long-term peak slightly greater for the higher-temperature operating mode. Calculations for Inventory Module 1 produce a similar response. Given the similarity of impacts, and that the lower-temperature operating mode impacts are generally bounded by the higher-temperature operating mode impacts, it was deemed unnecessary to perform detailed simulations for the lower-temperature operating mode under Inventory Module 1. The results would be similar to, but less than, those for the higher-temperature operating mode under Inventory Module 1, as reported in Section 8.3.1.2.1.1.

Table 8-49. Comparison of nominal scenario long-term consequences at the RMEI location[a] to groundwater protection standards during 10,000 years following repository closure for the higher-temperature repository operating mode under the Proposed Action and Inventory Module 1.

Modeled inventory	Radionuclide or type of radiation emitted	EPA Limit[b]	Mean peak[c]	95th-percentile peak[d]
Proposed Action	Combined radium-226 and radium-228,[e] picocuries per year	5	1.0 (1×10^{-11})[f]	1.0 (2×10^{-11})
	Gross alpha activity (including radium-226 but excluding radon and uranium),[e] picocuries per year	15	0.4 (2×10^{-8})	0.4 (1×10^{-8})
	Combined beta and photon emitting radionuclides,[g] millirem per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	2×10^{-5}	1×10^{-4}
Inventory Module 1	Combined radium-226 and radium-228,[e] picocuries per year	5	1.0 (3×10^{-10})	1.0 (3×10^{-11})
	Gross alpha activity (including radium-226 but excluding radon and uranium),[e] picocuries per year	15	0.4 (3×10^{-8})	0.4 (4×10^{-8})
	Combined beta and photon emitting radionuclides,[g] millirem per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume	4	3×10^{-5}	2×10^{-4}

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is located approximately 18 kilometers (11 miles) downgradient from the repository.
b. Environmental Protection Agency limits set forth in 40 CFR Part 197.30.
c. Based on 300 simulations of total system performance, each using random samples of uncertain parameters.
d. Represents a value for which 285 out of the 300 simulations yielded a smaller value.
e. Includes natural background radiation.
f. Value in parentheses is the incremental increase over background radiation that would be attributable to the potential repository.
g. This represents a bounding (overestimate) of the maximum dose to any organ because the different radionuclides would affect different organs preferentially.

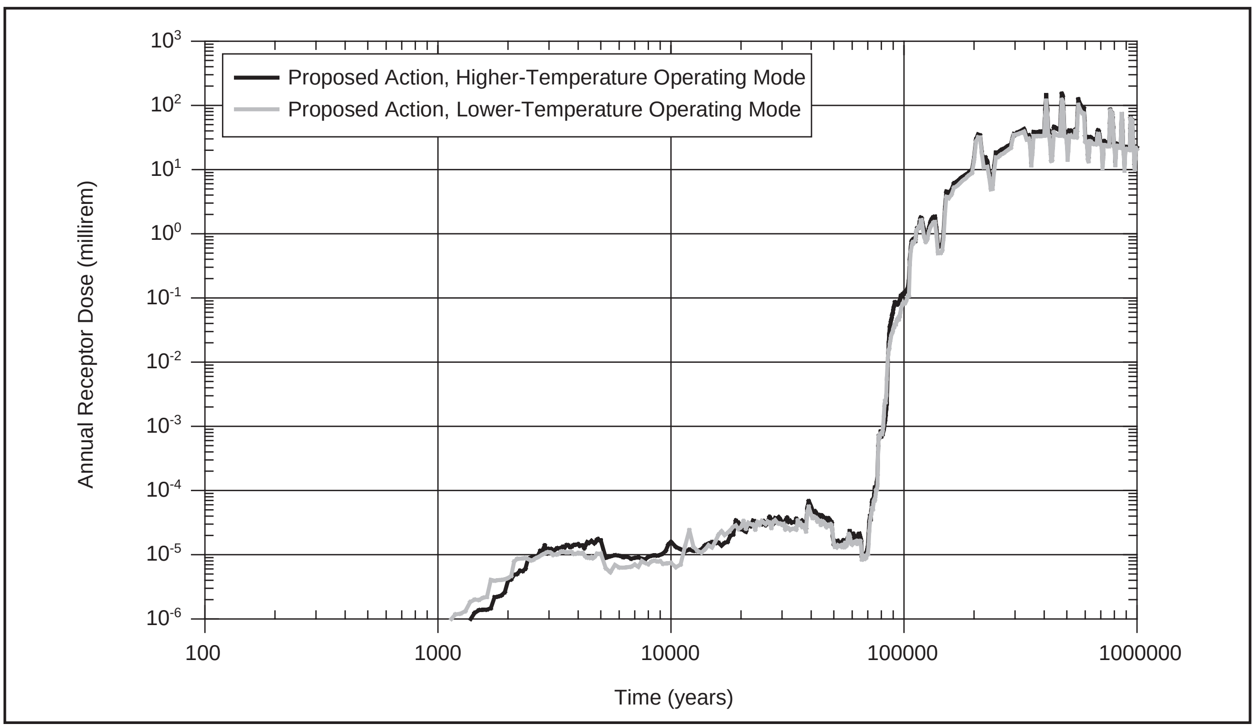

Figure 8-4. Comparison of mean annual individual dose (based on 300 simulations of total system performance, each using random samples of uncertain parameters) at the RMEI location for the higher- and lower-temperature operating modes. (Note use of logarithmic scale for both axes.)

8.3.1.2.2 *Waterborne Chemically Toxic Material Impacts*

A number of nonradioactive materials that DOE would place in the repository are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials under Inventory Module 1.

The inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action is identified by element in Appendix I, Section I.3. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1) identified which of the chemically toxic materials might pose a risk to human health. Only chromium, molybdenum, nickel, and vanadium were identified as potentially posing such a risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. The analysis was performed under the conservative assumption that all chromium dissolves in hexavalent form. The results of the bounding analysis are summarized for both the Proposed Action and Inventory Module 1 in Table 8-50. In some cases a Maximum Containment Level or Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day. More detail on these comparative measures can be found in Chapter 5, Section 5.6, and Appendix I, Section I.6.2.5.

Table 8-50. Peak concentration of waterborne chemical materials released during 10,000 years after closure estimated using bounding calculations for the Proposed Action and Inventory Module.

Modeled inventory	Material	Estimated concentration in well water (milligram per liter)	Maximum Contaminant Level Goal (milligram per liter)	Estimated intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Proposed Action	Chromium (VI)	0.01	0.1[a]	0.0004	0.005[b]
	Molybdenum	0.009	NA[c]	0.0003	0.005[d]
	Nickel	0.04	NA	0.001	0.02[e]
	Vanadium	0.0002	NA	0.000006	0.007[f]
Inventory Module 1	Chromium (VI)	0.02	0.1[a]	0.0006	0.005[b]
	Molybdenum	0.01	NA	0.0004	0.005[d]
	Nickel	0.05	NA	0.002	0.02[e]
	Vanadium	0.0003	NA	0.000009	0.007[f]

a. 40 CFR 191.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in well water is calculated to be below the Maximum Contaminant Level Goal or yield intakes well below the Oral Reference Dose for Inventory Module 1, there is no further need to refine the calculation to account for physical processes that would limit mobilization of this material or delay or dilute it during transport in the geosphere.

8.3.1.2.3 *Atmospheric Radioactive Material Impacts*

Using the analysis methods described in Chapter 5, Section 5.5, DOE estimated the impacts of carbon-14 releases to the atmosphere within 10,000 years past closure for Inventory Module 1. As explained in Appendix I, Section I.7.1, the maximum release rate to the ground surface for this period is the same for both Inventory Modules 1 and 2 as for the Proposed Action. Therefore, there would be no incremental atmospheric radioactive material impacts for Inventory Module 1 for the Proposed Action.

8.3.1.3 INCREMENTAL IMPACTS FOR INVENTORY MODULE 2

DOE addressed the long-term consequences from Inventory Module 2 by analyzing the effects of disposing waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in addition to the material in Inventory Module 1. Table 8-43 lists the average inventory of the additional waste packages containing Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. The following sections discuss these impacts in terms of waterborne radioactive releases, chemically toxic materials waterborne release, and atmospheric radioactive material releases.

8.3.1.3.1 *Waterborne Radioactive Material Impacts*

The addition of Greater-Than-Class-C and Special-Performance-Assessment-Required wastes is the only difference between Inventory Modules 1 and 2. Inventory Module 2 was modeled as an incremental inventory; specifying only the Greater-Than-Class-C and Special-Performance- Assessment-Required waste as the radionuclide inventory. The results of the incremental inventory simulations constitute the additional impacts of Inventory Module 2 over those of Module 1. In addition, they represent the dose attributable solely to the Greater-Than-Class-C and Special- Performance-Assessment-Required waste.

Table 8-51 lists the incremental consequences for an individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 during 10,000 years and 1 million years following repository closure. Peak impacts from waterborne radioactive materials for Module 2 would be less than 1 percent higher for 1,000,000 years after repository closure. For the first 10,000 years following the repository closure, the Module 2 impact would remain very small (mean annual individual dose of 0.0007 millirem, compared to the Environmental Protection Agency standard of 15 millirem for this period as defined in 40 CFR Part 197).

Table 8-51. Incremental increase (millirem) in mean peak individual annual dose at the RMEI location[a] under Inventory Module 2 over the mean peak individual annual dose under Inventory Module 1 during 10,000 and 1 million years after repository closure.

Postclosure period	Incremental Increase[b]
10,000 years	0.0007
1,000,000 years	0.3

a. The RMEI location, defined in 40 CFR Part 197, is where the predominant groundwater flow path crosses the boundary of the controlled area and is approximately 18 kilometers (11 miles) downgradient from the repository.

b. Based on 300 simulations each for Inventory Modules 1 and 2 using random samples of uncertain parameters.

8.3.1.3.2 *Waterborne Chemically Toxic Material Impacts*

A number of nonradioactive materials that DOE would place in the repository are hazardous to human health at high concentrations in water. This section examines the consequences to individuals in the Amargosa Desert from releases of these nonradioactive materials under Inventory Module 2.

The inventory of chemically toxic materials that would be emplaced in the repository under the Proposed Action is identified by element in Appendix I, Section I.3. Based on this inventory, a screening analysis (described in Appendix I, Section I.6.1.) identified which of the chemically toxic materials could pose a risk to human health. Only chromium, molybdenum, nickel, and vanadium were identified as posing such a risk, and these elements were further evaluated in a bounding consequence analysis, as described in Appendix I, Section I.6.2. The results of the bounding analysis are summarized for both the Proposed Action and Inventory Module 2 in Table 8-52. In some cases a Maximum Contaminant Level Goal was available for comparison to the calculated concentration. In other cases, only an Oral Reference Dose was available. The Oral Reference Dose can be compared to the intake that would result for a 70-kilogram (154-pound) person drinking 2 liters (0.53 gallon) of water per day. More detail on these comparative measures can be found in Chapter 5, Section 5.6, and Appendix I, Section I.6.2.5.

Table 8-52. Peak concentration of waterborne chemical materials released during 10,000 years after closure estimated using bounding calculations for the Proposed Action and Inventory Module 2.

Modeled inventory	Material	Estimated concentration in well water (milligram per liter[a])	Maximum Contaminant Level Goal (milligram per liter)	Estimated intake rate for a 70-kilogram person (milligram per kilogram per day)	Oral Reference Dose (milligram per kilogram per day)
Proposed Action	Chromium (VI)	0.01	0.1[a]	0.0004	0.005[b]
	Molybdenum	0.009	NA[c]	0.0003	0.005[d]
	Nickel	0.04	NA	0.001	0.02[e]
	Vanadium	0.0002	NA	0.000006	0.007[f]
Inventory Module 2	Chromium (VI)	0.02	0.1	0.0006	0.005[b]
	Molybdenum	0.01	NA	0.0004	0.005[d]
	Nickel	0.06	NA	0.002	0.02[e]
	Vanadium	0.0003	NA	0.00001	0.007[f]

a. 40 CFR 191.51.
b. DIRS 148224-EPA (1999, all).
c. NA = not available.
d. DIRS 148228-EPA (1999, all).
e. DIRS 148229-EPA (1999, all).
f. DIRS 103705-EPA (1997, all).

Because the bounding concentration of chromium, molybdenum, nickel, and vanadium in well water is calculated to be below the Maximum Containment Level Goal or yield intakes well below the Oral Reference Dose for Inventory Module 2, there is no further need to refine the calculation to account for physical processes that would limit mobilization of this material or delay or dilute it during transport in the geosphere.

The incremental (that is, the increase in) consequences for an individual from the Greater-Than-Class-C and Special-Performance-Assessment-Required wastes in Inventory Module 2 over Inventory Module 1 during 10,000 years and 1 million years following repository closure is 4 percent for all four waterborne chemical materials of concern (chromium, molybdenum, nickel, and vanadium).

8.3.1.3.3 *Atmospheric Radioactive Material Impacts*

There would be no incremental impact for airborne carbon-14 releases for Inventory Module 2. None of the additional waste packages would contain a waste form in which carbon-14 would exist in gaseous form (that is, as carbon dioxide). As for the Proposed Action and Inventory Module 1, radon-222 would be released as a gas but would decay to a solid isotope before escaping from the repository region (see Appendix I, Section I.7.3).

8.3.2 CUMULATIVE IMPACTS FROM OTHER FEDERAL, NON-FEDERAL, AND PRIVATE ACTIONS

This section discusses potential cumulative impacts from other Federal, non-Federal, and private actions that could contribute to doses at the locations considered in the performance assessment of the Yucca Mountain Repository. The actions identified with the potential for long-term cumulative impacts are past, present, and reasonably future actions at the Nevada Test Site and past actions at the low-level radioactive waste disposal facility near Beatty, Nevada.

8.3.2.1 Past, Present, and Reasonably Foreseeable Future Actions at the Nevada Test Site

Historically, the primary mission of the Nevada Test Site was to conduct nuclear weapons tests. Nuclear weapons testing and other activities have resulted in radioactive contamination and have the potential for radioactive and nonradioactive contamination of some areas of the Nevada Test Site. These areas and the associated contamination and the potential for contamination were evaluated for potential cumulative impacts with postclosure impacts from the proposed Yucca Mountain Repository. This section discusses these Nevada Test Site activities, the locations where these activities occurred, and the potential for cumulative long-term impacts with the repository.

Unless otherwise identified, DOE derived the information in this section from the Nevada Test Site Final EIS (DIRS 101811-DOE 1996, all). The Yucca Mountain site is in the southwestern portion of the Nevada Test Site along its western boundary, as shown in Figure 8-2.

At the Nevada Test Site, seven categories of activities have resulted in radioactive contamination or have the potential to result in radioactive and nonradioactive contamination:

1. *Atmospheric Weapons Testing.* One hundred atmospheric detonations occurred before the signing of the Limited Test Ban Treaty in August 1963. Atmospheric tests included detonations at ground level, from towers or balloons, or from airdrops.

2. *Underground Nuclear Testing.* Approximately 800 underground nuclear tests have occurred at the Nevada Test Site. Chapter 3, Figure 3-2 shows the locations of these tests in relation to Yucca Mountain. They included deep underground tests to study weapons effects, designs, safety, and reliability, and shallow underground tests to study the peaceful application of nuclear devices for cratering.

3. *Safety Tests.* Between 1954 and 1963, 16 above-ground tests studied the vulnerability of weapons designs to possible accident scenarios.

4. *Nuclear Rocket Development Station.* Twenty-six experimental tests of reactors, nuclear engines, ramjets, and nuclear furnaces occurred between 1959 and 1973. Figure 8-3 shows the location of the Nuclear Rocket Development Station.

5. *Shallow Land Radioactive Waste Disposal.* DOE disposed of some radioactive waste generated during testing in shallow cells, pits, and trenches. Because of the significant thickness of alluvial material and high mean annual temperatures and low precipitation under the current climate regime, downward advection of groundwater to the water table is highly unlikely. Therefore, shallow burial continues to be an important waste disposal activity at the Nevada Test Site (DIRS 155159-REECo, 1994, all; DIRS 108774-Tyler et al. 1996, all).

Section 8.3.2.1.3 discusses present and potential future low-level radioactive waste disposal activities.

6. *Crater Disposal.* DOE disposed of contaminated soils and equipment collected during the decontamination of atmospheric testing areas and the consolidation of radioactively contaminated structures, and other bulk wastes, in subsidence craters at Yucca Flat in Area 3. Figure 8-3 shows the location of Area 3 on the Nevada Test Site.

7. *Greater Confinement Disposal.* In 1981, Greater Confinement Disposal began at Area 5 for low-level radioactive wastes not suitable for shallow land disposal. This waste includes some transuranic radionuclides. Figure 8-3 shows the location of Area 5 on the Nevada Test Site.

Table 8-53 lists the approximate inventory for each of these categories. Atmospheric testing, shallow underground testing, safety testing, and nuclear rocket development all resulted in a small (less-than-40-curie) source term, which would not contribute substantially to cumulative impacts. Additionally, the inventories represented by crater disposal and shallow-land disposal were determined to not be important to cumulative impact considerations. Only the deep underground testing and greater confinement

Table 8-53. Summary of radioactivity on the Nevada Test Site (January 1996).[a]

Source	Area	Environmental media	Major known isotopes or wastes	Depth range	Approximate inventory (curies)
Atmospheric weapons testing	Aboveground nuclear weapon proving area	Surficial soils and test structures	Americium, cesium, cobalt, plutonium, europium, strontium	At land surface	20
Underground testing: shallow underground tests	Underground nuclear testing areas	Soils and alluvium	Americium, cesium, cobalt, europium, plutonium, strontium	Less than 61 meters[b]	1 at land surface; unknown at depth
Underground testing: deep underground tests	Underground nuclear testing areas	Soils, alluvium, and consolidated rock	Tritium, fission, and activation products	Typically less than 640 meters, but might be deeper	130 million[c]
Safety tests	Aboveground experimental areas	Surficial soils	Americium, cesium, cobalt, plutonium, strontium	Less than 0.9 meter	35
Nuclear rocket development area	Nuclear rocket motor, reactor, and furnace testing area	Surficial soils	Cesium, strontium	Less than 3 meters	1
Shallow land disposal	Waste disposal landfills	Soils and alluvium	Dry-packaged low-level and mixed wastes	Less than 9 meters	500,000[d,e]
Crater disposal	Test-induced subsidence crater with sidewalls, cover, and drainage	Soils and alluvium	Bulk contaminated soils and equipment	Less than 30 meters	1,250[d,f]
Greater confinement disposal	Monitored underground waste disposal	Soils and alluvium	Tritium, americium	37 meters	9.3 million[d,g]

a. Source: DIRS 101811-DOE (1996, p. 4-6). This table uses information and terminology from that document and is for information purposes only.
b. To convert meters to feet, multiply by 3.2808.
c. Source: DIRS 157116-Bowen et al. (2001, Table V, p. 21)
d. Inventory at time of disposal (not corrected for decay).
e. Inventory does not include prospective future low-level radioactive and mixed waste disposal (see Section 8.3.2.1.3).
f. Volume of waste considered for inventory was approximately 205,000 cubic meters (7.25 million cubic feet).
g. Volume of waste considered for inventory was approximately 300 cubic meters (10,000 cubic feet).

disposal categories represent substantial inventories that could, when combined with the repository inventory, potentially result in increased cumulative impacts.

8.3.2.1.1 *Underground Nuclear Testing*

The United States began a moratorium on the explosive testing of nuclear weapons in October 1992. As discussed in the Nevada Test Site EIS (DIRS 101811-DOE 1996), however, other weapons testing continues at the Test Site, including dynamic, hydrodynamic, and explosive tests. These tests are necessary for the continued assurance of the nuclear arsenal but do not result in nuclear explosions like those that were common during the Cold War. Environmental contamination is due largely to past weapons testing and not to the current limited activities at the Test Site. Although there are potential past and present impacts of the explosive testing of nuclear weapons, the long-lived radionuclides that such testing deposited far underground could pose future impacts, which this section evaluates.

As of September 23, 1992, the estimated total radionuclide source term for all tests was about 130 million curies (DIRS 157116-Bowen et al. 2001, Table V, p. 21). Because these radionuclides are either in or close to the water table and therefore subject to dissolution and possible transport by groundwater, they are referred to as the hydrologic source term. This source term represents the remaining radioisotopes (as of September 23, 1992) that could be available to the groundwater regime. However, because of the existence of multiple, complex migration pathways and limited characterization data, there is considerable uncertainty concerning the actual hydrologic source term. In recent years, the drilling of new characterization wells and the retrofitting of existing boreholes and wells have provided valuable new data that are now being integrated into the overall database so new evaluations can be made. These studies and planned future studies will help reduce the current levels of uncertainty concerning the quantity of radionuclides available for groundwater transport as well as uncertainty concerning both the mechanisms and consequences of radionuclide transport by groundwater flow at the Nevada Test Site. Testing with subcritical assemblies since 1994 has added quantities of material that are very small compared to the historical testing. Thus, the Department has based its analysis on the much larger inventory from historical testing (DIRS 156758-Crowe 2001, all).

There is recent evidence of plutonium migration from one underground test. Groundwater monitoring results indicate that plutonium has migrated about 1.3 kilometers (0.8 mile), possibly facilitated by the movement of very small and relatively mobile particles called *colloids* in the groundwater (DIRS 103282-Kersting et al. 1999, p. 59). No radioactive contamination attributable to underground tests has been detected in monitoring wells off the Nevada Test Site. DOE is conducting further monitoring and research to study these and other potential radionuclide migration phenomenon.

The above information indicates that groundwater could transport radionuclides from underground nuclear tests at the Nevada Test Site. This transport could result in releases from underground testing at the sites analyzed for releases from the proposed repository. DOE did not make long-term performance assessment calculations for the underground testing inventory with the same rigor as the analyses for the repository, and there is much uncertainty related to the hydrogeologic system. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001, all). In addition, DOE has continued technical development of the Total System Performance Assessment since the publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. These efforts have resulted in an updated performance assessment referred to as the Total System Performance Assessment-Site Recommendation (TSPA-Site Recommendation; DIRS 153246-CRWMS M&O 2000). The results of this analysis for long-term impacts from the Yucca Mountain Repository are reported in Chapter 5 of this Final EIS. The TSPA-Site Recommendation evaluated the long-term performance of the Science and Engineering Report flexible design and included the best available information related to contaminant fate and transport. The results for the groundwater impacts from the repository in this analysis are substantially lower than reported in the Draft EIS. However, an update of this simplified scaling analysis used to estimate the potential cumulative impact from underground testing at the Nevada Test Site was not performed for the Final EIS because the principal factors affecting contaminant fate and transport remained essentially unchanged between the TSPA-Viability Assessment and the TSPA-Site Recommendation. DOE considers the estimates of Nevada Test Site groundwater impacts developed using the simplified model conservative and applicable for environmental evaluation. Further, any minor enhancements to these factors incorporated into the TSPA-Site Recommendation would have yielded results for an updated cumulative analysis well within the uncertainty reported for the analysis based on the TSPA-Viability Assessment. Therefore, DOE developed a simplified analysis that uses the TSPA-Viability Assessment (DIRS 101779-DOE 1998, all) repository infiltration and groundwater fate and transport models to scale groundwater impacts that could result from the underground test inventory. The analysis made the following assumptions for this calculation:

- The total 130-million-curie radionuclide inventory from underground testing at the Nevada Test Site would be available for transport. Tritium constitutes about 90 percent of the total underground testing inventory (DIRS 157116-Bowen et al. 2001, Table V, p. 21). However, the short half-life of tritium (about 12.5 years) would mean that radioactive decay would deplete the tritium inventory to insignificant levels in about 200 years, long before any Yucca Mountain releases would occur. Since potential impacts from tritium migration from the Test Site would not overlap repository impacts temporally, they would not be cumulative. Therefore, DOE did not consider them in this analysis.

- The radionuclide inventory available for transport at the repository would be the estimated curie content of the source material that would become wet in the 10,000-year analysis period. The analysis determined this amount by estimating the quantity of source material in the waste packages and cladding that are predicted to fail (*juvenile* and new *failures*) during the analysis period. Assuming that DOE would emplace 10,000 waste packages in the repository, the package failure rates developed in the TSPA-Viability Assessment indicate two waste package failures with 100 percent of contained elements exhibiting failed cladding. Since issuing the Draft EIS, DOE has continued to evaluate design features and operating modes that would reduce uncertainties in or improve long-term repository performance, including the waste package design, and improve operational safety and efficiency. The result of the design evolution process was the development of the Science and Engineering Report flexible design (DIRS 153849-DOE 2001, all). In addition, DOE has continued technical development of the Total System Performance Assessment since publication of the Draft EIS, including further site characterization, improvements to the engineered system design, system performance assessment calculations, and quality assurance and validation of results. These efforts have resulted in an updated performance assessment referred to as the Total System Performance Assessment-Site Recommendation [TSPA-Site Recommendation (DIRS 153246-CRWMS M&O 2000)]. The results of this analysis for long-term impacts from the Yucca Mountain Repository are reported in Chapter 5 of this Final EIS. The TSPA-Site Recommendation evaluated the long-term performance of the updated Science and Engineering Report flexible design and included the best available information related to contaminant fate and transport. The results for the groundwater impacts from the repository in this analysis are substantially lower than reported in the Draft EIS. However, an update of this simplified scaling analysis used to estimate the potential cumulative impact from underground testing at the Nevada Test Site was not performed for the Final EIS because the principal factors affecting contaminant fate and transport remained essentially unchanged between the TSPA-Viability Assessment and the TSPA-Site Recommendation. DOE considers the estimates of Nevada Test Site groundwater impacts developed using the simplified model conservative and applicable for environmental evaluation. Further, any minor enhancements to these factors incorporated into the TSPA-Site Recommendation would have yielded results for an updated cumulative analysis well within the uncertainty reported for the analysis based on the TSPA-Viability Assessment.

- The estimated total inventory for all underground tests at the Nevada Test Site was 130 million curies as of September 23, 1992 (DIRS 157116-Bowen et al. 2001, Table V, p. 21). As discussed above, the contribution to the total inventory from subcritical experiments is very small and is adequately accounted for by analyzing the inventory from historical testing (DIRS 156758-Crowe 2001, all). The Department only evaluated the radionuclides of interest (that is, those that result in 99 percent of the impact; technetium-99, iodine-129, and carbon-14) in this inventory (see Section 5.4.1 of the Draft EIS for details.)

- The total underground testing inventory available for transport would migrate through the same locations as those considered in this EIS for dose calculations for releases from the repository. This is very conservative because much of the water migrating from the underground test locations would discharge to locations other than those for releases from the proposed repository. Such locations include Oasis Valley, Ash Meadows, or the Amargosa Desert.

- The radionuclide-specific distribution coefficients, k_d, are assumed to be equal for source materials at the repository and the Nevada Test Site. This assumption recognizes that most of the nonvolatile radionuclide inventory at the Test Site is captured within the glass-like material resulting from the intense heat generated by past underground tests. The analysis assumed that the leachability of this material is not remarkably different than that of ceramic spent nuclear fuel pellets. Concentrations of the contaminants (curies per milliliter) in leachates are directly proportional to the source material (curies per gram) and the radionuclide-specific distribution coefficients.

- All contaminants originating on the Nevada Test Site would flow to the same discharge points as contaminants from Yucca Mountain, as modeled by the TSPA-Viability Assessment, and the peak groundwater concentrations of contaminants from the Test Site would coincide (in time and space) with the peak groundwater concentrations from repository contaminants.

- Concentrations of radionuclides in the groundwater would be diluted by total infiltration through the repository footprint and groundwater recharge for the repository and the Nevada Test Site, respectively.

The absolute potential cumulative Nevada Test Site groundwater impact can be estimated by comparison with the 10,000-year impacts presented in Table 5-4 of the Draft EIS. Based on these tables, the estimated cumulative Test Site impacts for the Proposed Action for the maximally exposed individual would be about 0.007 millirem per year at 20 kilometers. The dose to the RMEI at 18 kilometers, as described in Chapter 5, would be slightly higher. Therefore, the estimated total potential cumulative impact (Yucca Mountain impact plus Nevada Test Site impact) would be essentially (because of the small contribution from the proposed repository) 0.007 millirem per year to the RMEI.

Because of the large uncertainties in the current level of understanding of the hydrogeologic system, DOE has not attempted to model the actual groundwater transport of the Nevada Test Site with this simplified model. However, by assuming that the radionuclide contaminants in the groundwater at the Test Site would be transported in an identical manner to those from the repository and that peak concentrations would occur at precisely the same time, the Department believes that the resulting estimates of cumulative impacts from underground testing activities represent a reasonable upper bound of the actual cumulative impacts.

Uncertainties associated with Nevada Test Site groundwater impacts:

- *Source material concentration* – The concentration of contaminants within the source material is the parameter with the most sensitivity to outcome but also the parameter that the least is known about at the Nevada Test Site. However, the actual Test Site concentrations could be higher than those estimated for this analysis and still have little effect on the outcome. This is because, as the density of the Test Site inventory increases (that is, the radionuclide inventory is assumed to occupy a smaller volume), the quantity of infiltration “seen” by the contaminant would decrease because of the reduced footprint of the source term. Since both of these terms (radionuclide density and water infiltration per unit area) are directly proportional to the calculated groundwater concentration, they would tend to offset one another. However, for conservatism, the assumption was made that all of the Test Site source term for radionuclides of interest was concentrated only in the affected soil at Yucca Flat. This assumption could have resulted in an overestimate of the Test Site concentration and potential impacts by as much as two.

- *Travel distances and times* – The conservative assumption was made that the contaminants from Yucca Mountain and the Nevada Test Site would travel along the same pathways (those assumed for Yucca Mountain in the TSPA-Viability Assessment) and at the same time to maximize potential impacts. If more realistic modeling had been performed, the peak contaminate concentrations from Yucca Mountain and the Test Site probably would not coincide and the Test Site contribution to the cumulative impacts would therefore be smaller than those estimated.

- *Solute partition coefficients* – These coefficients as described in the literature are known to vary by orders of magnitude depending on soil and source zone material types. Because the precise nature of the soils at the Nevada Test Site was not considered in the simplified analysis, the actual result could be different. However, these values are not readily available and are impossible to estimate accurately with currently available data.

- *Contaminant mobilization* – To simplify the analysis, the assumption was made that the waste isolated in engineered barrier systems for the Yucca Mountain Repository and the waste dispersed in glass-like material from underground nuclear blasts at the Nevada Test Site will have the same release characteristics. The actual mechanisms for waste mobilization for Test Site underground testing contamination are largely unknown. The actual differences in the mobilization of the contaminants could result in changes (larger or smaller) in the impact estimates, however, due to the relative size of the calculated impacts, coupled with the other conservatisms assumed in this simplified analysis, they are not likely to influence the conclusion.

- *Groundwater flow direction and discharge points* – If realistic modeling was performed, and adequate characterization data to support that modeling was available, then it is extremely unlikely that the modeling would show that all contaminants resulting from underground testing across the Nevada Test Site would migrate to only one discharge point and that point would be the same point of discharge as the releases from the Yucca Mountain Repository. More detailed information on actual groundwater flow would likely serve to reduce the estimated impact of the Test Site inventory.

8.3.2.1.2 *Greater Confinement Disposal*

Waste disposed of at the Nevada Test Site under Greater Confinement Disposal constitutes a radiological source term that is less than 10 percent of the repository radionuclide source term immediately available for groundwater transport when the first waste packages at the Yucca Mountain Repository are assumed to have initially degraded (that is, 2 percent of the total repository radionuclide source term). The waste disposed of by Greater Confinement Disposal was placed in boreholes that are approximately 37 meters (120 feet) deep; the waste itself is no closer than approximately 21 meters (70 feet) to the surface. DOE has reviewed analyses related to the Nevada Test Site and has concluded that there is no credible pathway for long-term releases of materials by resuspension of nonvolatile radionuclides because the material is sufficiently far below the surface. In addition, evapotranspiration exceeds precipitation in this region, which, coupled with the fact that the boreholes are sufficiently above the water table (more than 125 meters), indicates that there is no credible release scenario for Greater Confinement Disposal material to enter the groundwater. Therefore, DOE expects no cumulative impacts from Greater Confinement Disposal activities.

8.3.2.1.3 *Future Nevada Test Site Low-Level Waste Disposal*

The Nevada Test Site is a disposal site for low-level radioactive waste generated by DOE-approved generators. Managed radioactive waste disposal operations began in the early 1960s, and DOE has disposed of low-level, transuranic, mixed, and classified low-level wastes in selected pits, trenches, landfills, and boreholes on the Nevada Test Site. Environmental impacts from the disposal of low-level waste at the Nevada Test Site are discussed in the Nevada Test Site Final EIS (DIRS 101811-DOE 1996, pp. 2-15 to 2-17). The current source term of low-level and mixed wastes in shallow land disposal on the Nevada Test Site does not constitute a substantial inventory in relation to the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). However, shallow burial of low-level radioactive waste continues to be an important waste disposal activity at the Nevada Test Site. Therefore, this section evaluates reasonably foreseeable future activities in this category as a potential cumulative impact.

Waste disposal activities on the Nevada Test Site occur at two specific locations. They are the Area 3 and Area 5 Radioactive Waste Management Sites. The Area 3 Radioactive Waste Management Site is on Yucca Flat and covers an area of approximately 0.2 square kilometer (50 acres). DOE uses conventional landfill techniques to dispose of contaminated debris from the Nevada Test Site Atmospheric Testing Debris Disposal Program and packaged bulk low-level waste from other DOE sites in subsidence craters from underground nuclear tests. The estimated total remaining capacity for low-level waste in the Area 3 site is 1.8 million cubic meters (64 million cubic feet) (DIRS 103224-DOE 1998, Section A.5.2) .

DOE has used the Area 5 Radioactive Waste Management Site since 1961 to dispose of low-level waste and classified low-level waste from Nevada Test Site operations. In 1978, the Test Site began accepting low-level waste generated by other DOE sites. The total area of the Area 5 site is 3 square kilometers (740 acres). The developed portion occupies 0.37 square kilometer (92 acres) in the southeast corner and contains 17 landfill cells (pits and trenches), 13 Greater Confinement Disposal boreholes, and a transuranic waste storage pad. DOE is seeking a Resource Conservation and Recovery Act permit for Pit 3 as a mixed-waste disposal unit. In the future, if the mixed-waste volume warranted it, the Department might consider obtaining a new unit and, hence, a new permitted facility. However, current projected waste volumes do not indicate the need for an additional mixed-waste disposal unit at this time. The estimated total remaining capacity for low-level waste in the Area 5 Radioactive Waste Management Site is 1.2 million cubic meters (42 million cubic feet) (DIRS 103224-DOE 1998, Section A.5.3).

As discussed in Section 8.2.12.1, DOE projects a need for 1.1 million cubic meters of capacity for low-level waste disposal at the Nevada Test Site through 2070 (DIRS 155856-DOE 2000, Table 4-1).

The Final Waste Management Programmatic EIS (DIRS 101816-DOE 1997, Summary) reported volumes of radioactive waste DOE may dispose of at the Nevada Test Site for "current plus 20 years" of waste disposal. The current inventory plus 20 years of additional disposal inventory would total 3,000 cubic meters (106,000 cubic feet) of low-level mixed waste, 1,700 cubic meters (60,000 cubic feet) of low-level waste, and 610 cubic meters (21,500 cubic feet) of transuranic waste (DIRS 101816-DOE 1997, Summary, p. 102). The Nevada Test Site Final EIS (DIRS 101811-DOE 1996, Table 4-1, p. 4-6) estimates the total current inventory already in shallow disposal at the Nevada Test Site to be 500,000 curies at the time of disposal (uncorrected for decay to the present time).

According to the Final Waste Management Programmatic EIS, the only expected groundwater impacts from low-level mixed, low-level radioactive, and transuranic waste disposal at the Nevada Test Site in excess of regulatory limits are for the hazardous chemicals 1,2-dichloroethane, methylene chloride, and benzene, and those only under Regionalized Alternative 3 and the Preferred Alternative in that EIS (DIRS 101816-DOE 1997, p. 11-61). None of these hazardous chemicals would be in the Yucca Mountain

Repository inventory, so there would be no potential cumulative impacts from those chemicals from the Proposed Action or Inventory Module 1 or 2.

DOE has estimated potential long-term impacts from radioactive material disposed of at the Nevada Test Site. DOE based its calculations of long-term atmospheric releases for the Nevada Test Site on estimates of the inventory at the Test Site that could be accessible by residents around the area. For this calculation, the Department considered three potential sources of radionuclide releases:

- The Area 3 radioactive waste disposal area
- The Area 5 radioactive waste disposal area
- Soil sites around the Nevada Test Site that are contaminated at or near the surface from nuclear weapons testing

Because this material is not near the water table and because evapotranspiration exceeds precipitation in this area, there is no credible release scenario for this material to enter the groundwater. DOE postulated that, over time, weathering at the site could resuspend contaminants in the air and transport them from the contaminated areas to offsite residents. Therefore, DOE performed calculations using current meteorological information for the Nevada Test Site and site-specific resuspension factors to estimate the amount of material that could be released off the site. To ensure conservatism in the estimate, DOE assumed that the three sources listed above were in the same location (even though in reality they are separated by large distances) and that a future resident could be as near as 100 meters (330 feet) from the site. Analyses based on these assumptions are likely to overestimate the true impacts to a future resident because they result in a calculated total emission and radiation dose that is probably higher than if a resident were within 100 meters of a single site.

Based on these conservative assumptions, DOE calculated that the total radiation dose from the three sources could be approximately 7 millirem for each year of exposure during the first 10,000 years, and DOE does not expect that the dose would increase beyond that value for as long as 1,000,000 years. If a resident received this dose as long as 70 years, that person’s lifetime dose could be as high as 490 millirem, which could result in an increased risk of fatal cancer of 0.0002.

8.3.2.2 Past Actions and Present Actions at the Beatty Low-Level Radioactive Waste Disposal and Hazardous Waste Treatment Storage and Disposal Facilities

A low-level radioactive waste disposal facility, formerly operated by U.S. Ecology, a subsidiary of American Ecology, is 16 kilometers (10 miles) southeast of Beatty, Nevada, and 180 kilometers (110 miles) northwest of Las Vegas. This site is about 15 kilometers (9.3 miles) west of the proposed Yucca Mountain Repository (see Figure 8-2). The disposal facility, which opened in 1962, covers roughly 0.14 square kilometer (35 acres) of unlined trenches. Acceptance of low-level radioactive waste ended December 31, 1992 (DIRS 101815-DOE 1997, Chapter 4, Table 4-17). The Nevada State Health Division formally accepted permanent custody of the low-level radioactive commercial waste disposal in a letter to American Ecology dated December 30, 1997 (DIRS 148088-AEC 1998, all). An adjacent U.S. Ecology facility remains open for hazardous waste disposal.

From 1962 through 1992, the inventory shipped to the Beatty low-level radioactive waste facility totaled 137,000 cubic meters (4.8 million cubic feet) in volume (DIRS 101815-DOE 1997, Chapter 4, Table 4-17) with radioactivity of about 640,000 curies (DIRS 101815-DOE 1997, Chapter 4, Table 4-18). The radioactivity in this sum was measured by year of shipment (that is, it is not corrected for decay since that time).

The Manifest Information Management System (DIRS 148160-MIMS 1992, all) calculated the total radionuclide inventory the Beatty facility received from 1986 through 1992, which represents 29 percent of the total undecayed inventory at that facility. Even if multiplied by a factor of 3 to 4 to compensate for the period (1962 to 1985) for which the Manifest Information Management System did not provide information, the source term represents a small percentage of the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). Therefore, cumulative long-term impacts from the Beatty Low-Level Radioactive Waste Disposal Facility with the repository would be very small.

The U.S. Ecology Hazardous Waste Treatment, Storage and Disposal Facility is a Resource Conservation and Recovery Act-permitted facility, with engineered barriers and systems and administrative controls that minimize the potential for offsite migration of hazardous constituents.

8.4 Cumulative Transportation Impacts

This section discusses the results of the cumulative impact analysis of transportation. Paralleling the transportation analyses of the Proposed Action in Chapter 6, potential national transportation cumulative impacts from Inventory Module 1 or 2, and past, present, and reasonably foreseeable future actions, are presented in Section 8.4.1. Potential cumulative impacts with construction and operation of the Nevada transportation implementing rail and heavy-haul truck alternatives are included in Section 8.4.2.

The shipment of Inventory Module 1 or 2 to the repository would use the same transportation routes, but would take more shipments and an additional 14 years compared to the Proposed Action. Table 8-2 lists the estimated number of shipments for Modules 1 and 2. Impacts from Module 1 or 2 would be similar because the shipping rate would be the same for spent nuclear fuel and high-level radioactive waste and only about 3 percent more shipments would be made over the 38-year period under Module 2 to transport Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. Because the difference in impacts between Inventory Modules 1 and 2 would be small, the following discussions present the impacts from both modules as being the same.

8.4.1 NATIONAL TRANSPORTATION

This section describes cumulative impacts from national transportation. Section 8.4.1.1 presents potential cumulative impacts from shipping Inventory Module 1 or 2 from commercial nuclear generating sites and DOE facilities to the proposed Yucca Mountain Repository (Section 8.4.1.1). Section 8.4.1.2 presents potential cumulative national transportation impacts for the Proposed Action and Module 1 or 2 when combined with past, present, and reasonably foreseeable future shipments of radioactive material.

8.4.1.1 Inventory Module 1 or 2 Impacts

This section describes the potential cumulative impacts of loading operations at generating sites and incident-free radiological impacts, vehicle emission impacts, and accident impacts associated with transportation activities for Inventory Module 1 or 2. Cumulative impact results are provided for the mostly legal-weight truck and mostly rail scenarios which are described in Chapter 6. The section also describes potential cumulative impacts from transportation of other materials, personnel, and repository-generated waste for Modules 1 or 2. Appendix J contains additional detailed analysis results.

Loading operations would be extended for an additional 14 years to load the greater quantities of spent nuclear fuel and high-level radioactive waste under Inventory Module 1 or 2. The impacts of routine loading operations described for the Proposed Action in Chapter 6, Section 6.2.2, would increase for Module 1 or 2 due to the additional inventory. Therefore, the increase in dose to the public would be

The Manifest Information Management System (DIRS 148160-MIMS 1992, all) calculated the total radionuclide inventory the Beatty facility received from 1986 through 1992, which represents 29 percent of the total undecayed inventory at that facility. Even if multiplied by a factor of 3 to 4 to compensate for the period (1962 to 1985) for which the Manifest Information Management System did not provide information, the source term represents a small percentage of the radionuclide source term immediately available for groundwater transport from the repository when the first waste packages initially degrade (that is, 2 percent of the total repository radionuclide source term). Therefore, cumulative long-term impacts from the Beatty Low-Level Radioactive Waste Disposal Facility with the repository would be very small.

The U.S. Ecology Hazardous Waste Treatment, Storage and Disposal Facility is a Resource Conservation and Recovery Act-permitted facility, with engineered barriers and systems and administrative controls that minimize the potential for offsite migration of hazardous constituents.

8.4 Cumulative Transportation Impacts

This section discusses the results of the cumulative impact analysis of transportation. Paralleling the transportation analyses of the Proposed Action in Chapter 6, potential national transportation cumulative impacts from Inventory Module 1 or 2, and past, present, and reasonably foreseeable future actions, are presented in Section 8.4.1. Potential cumulative impacts with construction and operation of the Nevada transportation implementing rail and heavy-haul truck alternatives are included in Section 8.4.2.

The shipment of Inventory Module 1 or 2 to the repository would use the same transportation routes, but would take more shipments and an additional 14 years compared to the Proposed Action. Table 8-2 lists the estimated number of shipments for Modules 1 and 2. Impacts from Module 1 or 2 would be similar because the shipping rate would be the same for spent nuclear fuel and high-level radioactive waste and only about 3 percent more shipments would be made over the 38-year period under Module 2 to transport Greater-Than-Class-C and Special-Performance-Assessment-Required wastes. Because the difference in impacts between Inventory Modules 1 and 2 would be small, the following discussions present the impacts from both modules as being the same.

8.4.1 NATIONAL TRANSPORTATION

This section describes cumulative impacts from national transportation. Section 8.4.1.1 presents potential cumulative impacts from shipping Inventory Module 1 or 2 from commercial nuclear generating sites and DOE facilities to the proposed Yucca Mountain Repository (Section 8.4.1.1). Section 8.4.1.2 presents potential cumulative national transportation impacts for the Proposed Action and Module 1 or 2 when combined with past, present, and reasonably foreseeable future shipments of radioactive material.

8.4.1.1 Inventory Module 1 or 2 Impacts

This section describes the potential cumulative impacts of loading operations at generating sites and incident-free radiological impacts, vehicle emission impacts, and accident impacts associated with transportation activities for Inventory Module 1 or 2. Cumulative impact results are provided for the mostly legal-weight truck and mostly rail scenarios which are described in Chapter 6. The section also describes potential cumulative impacts from transportation of other materials, personnel, and repository-generated waste for Modules 1 or 2. Appendix J contains additional detailed analysis results.

Loading operations would be extended for an additional 14 years to load the greater quantities of spent nuclear fuel and high-level radioactive waste under Inventory Module 1 or 2. The impacts of routine loading operations described for the Proposed Action in Chapter 6, Section 6.2.2, would increase for Module 1 or 2 due to the additional inventory. Therefore, the increase in dose to the public would be about 42 person-rem based on 0.001 person-rem per metric ton of heavy metal and 42,000 additional MTHM (46,000 tons) (DIRS 104731-DOE 1986, Volume 2, p. E.6) for Modules 1 and 2. This dose could result in an additional 0.02 cancer fatality in the exposed population. Table 8-54 lists estimated radiological and industrial hazard impacts to involved workers for the routine loading operations under Module 1 or 2. The Proposed Action impacts are listed for comparison.

Table 8-54. Radiological and industrial hazard impacts to involved workers from loading operations.[a,b]

Impact	Proposed Action[b]		Inventory Module 1 or 2	
	Mostly legal-weight truck scenario	Mostly rail scenario	Mostly legal-weight truck scenario	Mostly rail scenario
Radiological				
Maximally exposed individual				
Dose (rem)[c]	12	12	12	12
Probability of latent cancer fatalities	0.005	0.005	0.005	0.005
Involved worker population				
Dose (person-rem)	15,000	4,200	32,000	8,400
Number of latent cancer fatalities	6.0	1.7	13	3.4
Industrial hazards				
Total recordable cases[d]	380	130	770	260
Lost workday cases[e]	200	70	400	130
Fatalities[f]	0.88	0.3	1.8	0.6

a. Includes all involved workers at all facilities and does not vary by operating mode.
b. Source: Chapter 6, Section 6.2.
c. Assumes 500 millirem per year to radiation workers. The average individual exposure was assumed to be 24 years for both the Proposed Action and Inventory Module 1 or 2 since 24 years is a conservatively long time to assume an individual would be involved in loading operations.
d. Total recordable cases based on a loss incidence rate of 0.084.
e. Lost workday cases based on a loss incidence rate of 0.046.
f. Fatalities based on a loss incidence rate of 0.000218.

Because noninvolved workers would not have tasks that involved radioactive exposure, there would be no or very small radiological impacts to noninvolved workers. For the reasons identified in Chapter 6, Section 6.2.2.2, industrial hazard impacts to noninvolved workers would be about 25 percent of the impacts to the individual worker shown in Table 8-54.

The impacts of loading accident scenarios under Inventory Module 1 or 2 would be the same as those described for the Proposed Action in Chapter 6, Section 6.2.4.1. The same type of single accident event and its impacts are applicable to shipments under the Proposed Action or Module 1 or 2. As summarized in Chapter 6, Section 6.2.4.1, the analysis results indicate that there would be no or very small potential radiological consequences from loading accident scenarios involving spent nuclear fuel or high-level radioactive waste. These consequences would bound the consequences from similar accidents involving Greater-Than-Class-C or Special-Performance-Assessment-Required waste because of the lower available radionuclide inventory (see Appendix A).

Table 8-55 lists radiological impacts to involved workers and the public and vehicle emission impacts from incident-free transportation for the mostly legal-weight truck and mostly rail scenarios. The analysis of impacts for the mostly legal-weight truck scenario assumed that shipments would use commercial motor carriers for highway transportation and general freight commercial services for rail transportation for the naval spent fuel shipments that cannot be transported by legal-weight trucks. The mostly rail analysis accounts for legal-weight truck shipments that would occur for the commercial nuclear generator sites that do not currently have the capacity to handle or load rail casks. In addition, for the mostly rail analysis, DOE assumed that it would use either a branch rail line or heavy-haul trucks in conjunction with an intermodal transfer station in Nevada to transport the large rail casks to and from the

Table 8-55. Radiological and vehicle emission impacts from incident-free national transportation.

Category	Proposed Action[a,b]		Inventory Module 1 or 2[c]	
	Mostly legal-weight truck scenario[d]	Mostly rail scenario[e]	Mostly legal-weight truck scenario[d]	Mostly rail scenario[e]
Involved worker				
Collective dose (person-rem)	14,000	3,700 - 4,600	28,000	7,100 - 8,800
Estimated number of latent cancer fatalities	5.6	1.5 - 1.9	11.2	2.8 - 3.5
Public				
Collective dose (person-rem)	5,000	1,200 - 1,600	9,700	2,200 - 3,100
Estimated number of latent cancer fatalities	2.5	0.6 - 0.82	5.0	1.1 - 1.6
Estimated vehicle emission-related fatalities	0.95	0.5 - 0.8	1.9	0.9 - 1.4

a. Source: Chapter 6, Section 6.2.3.
b. Impacts are totals for shipments over 24 years.
c. Impacts are totals for shipments over 38 years.
d. Includes rail shipments of naval spent nuclear fuel to Nevada, and intermodal transfer station and heavy-haul truck operations for this fuel in Nevada.
e. Includes legal-weight truck shipments from commercial nuclear generator sites that do not have the capacity to handle or load rail casks, and the rail and heavy-haul truck implementing alternatives for Nevada described in Chapter 6.

repository. The range provided in the table for the mostly rail scenario addresses the different possible rail and heavy-haul truck implementing alternatives described in Chapter 6. The lower end of the range reflects use of a branch rail line in Nevada and the upper end of the range reflects use of heavy-haul trucks in Nevada. The involved worker impacts in Table 8-55 include estimated radiological exposures of truck and rail transportation crews and security escorts for legal-weight truck and rail shipments; the public doses account for the public along the route, the public sharing the route, and the public during stops. The Inventory Module 1 or 2 impacts would exceed those of the Proposed Action due to the additional number of shipments.

DOE does not expect radiological impacts for maximally exposed individuals to change from the Proposed Action due to the conservative assumptions used in the analysis of the Proposed Action (see Chapter 6, Section 6.2.3). The assumptions for estimating radiological dose include the use of the maximum allowed dose rate and conservative estimates of exposure distance and time. For example, the U.S. Department of Transportation maximum allowable dose rate of 10 millirem per hour at a distance of 2 meters (6.6 feet) [40 CFR 173.44(b)] was used for estimating exposure to individuals. In addition, the conservative assumptions for exposure distance and time for workers (that is, crew members, inspectors, railyard crew member) and the public (that is, resident along route, person in a traffic jam, person at a service station, resident near a rail stop) for the Proposed Action are unlikely to be exceeded for Inventory Module 1 or 2 (see Chapter 6, Section 6.2.3).

Table 8-56 lists the radiological accident risk and traffic fatalities for transportation by mostly legal-weight truck and mostly rail for Inventory Module 1 or 2. The radiological accident risk measures the total impact of transportation accidents over the entire shipping campaign (24 years for the Proposed Action and 38 years for Module 1 or 2). The consequences from a maximum reasonably foreseeable accident scenario would be identical to those discussed for the Proposed Action (see Chapter 6, Sections 6.2.4.2.1 and 6.2.4.2.2) because the parameters and conditions for the hypothetical accident event involving spent nuclear fuel or high-level radioactive waste would be the same for a shipment under the Proposed Action or Module 1 or 2. In addition, the hypothetical accident would be bounding for accident scenarios involving Greater-Than-Class-C and Special-Performance-Assessment-Required wastes.

As summarized in Chapter 6, Section 6.1.3, and further described in Appendix J, in addition to the transportation of spent nuclear fuel and high-level radioactive waste to the repository, other materials

Table 8-56. Accident risk for mostly legal-weight truck and mostly rail scenarios.

Category	Proposed Action[a]		Inventory Module 1 or 2	
	Mostly legal-weight truck scenario	Mostly rail scenario	Mostly legal-weight truck scenario	Mostly rail scenario
Radiological accident risk				
Collective dose risk (person-rem)	0.46	0.8 - 1.0	0.87	1.3 - 1.6
Estimated number of latent cancer fatalities	0.00023	0.00041 - 0.00050	0.00043	0.00066 - 0.00080
Traffic accident fatalities	4.9	2.3 - 3.1	8.7	4.2 - 5.9

a. Source: Chapter 6, Section 6.2.4.2.

would require transportation to and from the proposed repository. These materials would include construction materials, consumables, repository components (disposal containers, drip shields, etc.), office and laboratory supplies, mail, and laboratory samples. Required transportation would also include personnel commuting to the Yucca Mountain site and the shipment of repository-generated wastes offsite for treatment, storage, or disposal.

The implementation of Inventory Module 1 or 2 would increase this transportation as a result of the additional required subsurface development and the longer time required for repository development, emplacement, and closure. However, even with the increased transportation of other material, personnel, and repository-generated wastes for Module 1 or 2, DOE would expect these transportation impacts to be small contributors to the total transportation impacts on a local, state, and national level with no large cumulative impacts based on the analysis of the Proposed Action in Section 6.1.3. The annual air quality impacts for Inventory Module 1 or 2 would be the same as those conservatively estimated in Section 6.1.3 and, therefore, no cumulative air quality impacts would be expected in the Las Vegas airshed, which is in nonattainment for carbon monoxide. Table 8-57 summarizes fatalities from transporting other materials, personnel, and repository-generated waste. The estimated fatalities assume truck shipments in Nevada which would have higher potential impacts than shipments by rail. The Proposed Action impacts are listed in the table for comparison.

Table 8-57. Impacts from transportation of materials, consumables, personnel, and waste.[a,b]

Category	Proposed Action		Inventory Module 1 or 2	
	Kilometers traveled[c]	Fatalities	Kilometers traveled (Module 1/Module 2)	Fatalities (Module l/Module 2)
Materials (including repository components)	130,000,000 - 270,000,000	4.1 - 7.8	170,000,000 - 310,000,000	5.6 - 9.8
Personnel	480,000,000 - 800,000,000	5.4 - 9.2	640,000,000 - 930,000,000	7.3 - 11
Repository-generated waste				
Hazardous	57,000 - 71,000	0.001 - 0.002	110,000 - 170,000	0.002 - 0.003
Low-level radioactive	230,000 - 320,000	0.004 - 0.006	430,000 - 1,000,000	0.008 - 0.02
Nonhazardous solid	5,600,000 - 10,400,000	0.1 - 0.2	7,000,000 - 9,500,000	0.13 - 0.18
Totals	***610,000,000 - 1,100,000,000***	***9.6 - 17***	***820,000,000 - 1,300,000,000***	***13 - 20***

a. Totals might differ from sums of values due to rounding.
b. Source: Appendix J, Section J.3.6.
c. To convert kilometers to miles, multiply by 0.62137.

8.4.1.2 Cumulative Impacts from the Proposed Action, Inventory Module 1 or 2, and Other Federal, Non-Federal, and Private Actions

The overall assessment of cumulative national transportation impacts for past, present, and reasonably foreseeable future actions concentrated on the cumulative impacts of offsite transportation, which would yield potential radiation doses to a greater portion of the general population than onsite transportation and would result in fatalities from traffic accidents. The collective dose to workers and to the general population was used to quantify overall cumulative radiological transportation impacts. This measure was chosen because it could be related directly to latent cancer fatalities using a cancer risk coefficient and because of the difficulty in identifying a maximally exposed individual for shipments throughout the United States from 1943 through 2047. Operations at the Hanford Site and the Oak Ridge Reservation began in 1943, and 2047 is when the EIS analysis assumed that radioactive material shipments to the repository for Inventory Module 1 or 2 would end. The source of this cumulative transportation impacts analysis is the Yucca Mountain EIS Environmental Baseline File on transportation (DIRS 104800-CRWMS M&O 1999, Section 7.0), with the exception of impacts from the Proposed Action and Module 1 or 2, which are from Table 8-55.

The cumulative impacts of the transportation of radioactive material would consist of impacts from:

- Historic DOE shipments of radioactive material associated with the Nevada Test Site, the Idaho National Engineering and Environmental Laboratory, the Savannah River Site, the Hanford Site, the Oak Ridge Reservation, and naval spent nuclear fuel and test specimens

- Reasonably foreseeable actions that include the transportation of radioactive material identified in DOE Environmental Policy Act analyses; for example, the Nevada Test Site Environmental Impact Statement (DIRS 101811-DOE 1996, all), the Department of Energy Spent Nuclear Fuel Management Environmental Impact Statement (DIRS 101802-DOE 1995, all; DIRS 101812-DOE 1996, all), and the Final Department of Energy Waste Management Environmental Impact Statement (DIRS 101816-DOE 1997, all) (see Table 8-58). In some cases, transportation impacts included impacts that may have been double counted. For example, the transportation impacts from shipping 40,000 MTHM of spent nuclear fuel to a potential Private Fuel Storage Facility in Tooele County, Utah (DIRS 152001-NRC 2000, all) were included in Table 8-58, but the transportation impacts from the Proposed Action were not decreased to account for this 40,000 MTHM. Table 8-58 also includes reasonably foreseeable projects that include limited transportation of radioactive material (for example, shipment of submarine reactor components from the Puget Sound Naval Shipyard to the Hanford Site for burial, and shipments of uranium billets and low-specific-activity nitric acid from the Hanford Site to the United Kingdom). In addition, for reasonably foreseeable future actions where a preferred alternative was not identified or a Record of Decision has not been issued, the analysis used the alternative estimated to result in the largest transportation impacts. While this is not an exhaustive list of the projects that could include limited transportation of radioactive material, it indicates that the transportation impacts associated with such projects are low in comparison to major projects or general transportation.

- General radioactive materials transportation that is not related to a particular action; for example, shipments of radiopharmaceuticals to nuclear medicine laboratories and shipments of commercial low-level radioactive waste to commercial disposal facilities

- Shipments of spent nuclear fuel, high-level radioactive waste, Greater-Than-Class-C waste, and Special-Performance-Assessment-Required waste under the Proposed Action or Inventory Module 1 or 2

Table 8-58 summarizes the worker and general population doses from the transport of radioactive material. The estimated total cumulative transportation-related collective worker doses from the mostly legal-weight truck shipments (past, present, and reasonably foreseeable actions) with the Proposed Action would be about 360,000 person-rem (140 latent cancer fatalities), and with Inventory Module 1 or 2 about 410,000 person-rem (160 latent cancer fatalities). The estimated total general population doses for the mostly legal-weight truck shipments would be about 320,000 person-rem (160 latent cancer fatalities) with the Proposed Action, and about 350,000 person-rem (180 latent cancer fatalities) with Module 1 or 2. Most of the dose for workers and the general population would be due to general transportation of radioactive material. The estimated total cumulative number (workers plus population) of latent cancer fatalities with the Proposed Action would be about 300, and about 340 with Module 1 or 2. To place

Table 8-58. Cumulative transportation-related radiological doses, latent cancer fatalities, and traffic fatalities.[a]

Category	Worker dose (person-rem)	General population dose (person-rem)	Traffic fatalities
Historical DOE shipments (DIRS 101811-DOE 1996, all)	330	230	NL[b]
Reasonably foreseeable actions			
Private Fuel Storage Facility (DIRS 152001-NRC 2000, all)	29	190	0.78
Sodium-Bonded Spent Nuclear Fuel (DIRS 157167-DOE 2000, all)	0.0044	0.032	0.0001
Idaho High-Level Waste and Facilities (DIRS 155100-DOE 1999, all)	530	2,900	0.1
Surplus Plutonium Disposition (DIRS 118979-DOE 1999, all)	60	67	0.053
Sandia National Laboratories Site-Wide EIS (DIRS 157155-DOE 1999, all)	94	590	1.3
Depleted Uranium Hexafluoride (DIRS 152493-DOE 1999, all)	--[c]	750	4
Tritium Production in a Commercial Light Water Reactor (DIRS 157166-DOE 1999, all)	16	80	0.06
Parallex Project (DIRS 157153-DOE 1999, all)	0.00001	0.00007	0.00005
Los Alamos National Laboratory Site-Wide EIS (DIRS 157154-DOE 1999, all)	580	310	8
Plutonium Residues at Rocky Flats (DIRS 155932-DOE 1998, all)	2.1	1.3	0.0078
Import of Russian Plutonium-238 (DIRS 157156-DOE 1993, all)	1.8	4.4	0.0036
Nevada Test Site expanded use (DIRS 101811-DOE 1996, all)	--	150[d]	8
Spent nuclear fuel management (DIRS 101802-DOE 1995, all; DIRS 101812-DOE 1996, all)	360	810	0.77
Waste Management PEIS (DIRS 101816-DOE 1997, all)[e]	16,000	20,000	36
Waste Isolation Pilot Plant (DIRS 101814-DOE 1997, all)	790	5,900	5
Molybdenum-99 production (DIRS 101813-DOE 1996, all)	240	520	0.1
Tritium supply and recycling (DIRS 103208-DOE 1995, all)	--	--	0.029
Surplus HEU disposition (DIRS 103216-DOE 1996, all)	400	520	1.1
Storage and Disposition of Fissile Materials (DIRS 103215-DOE 1996, all)	--	2,400[d]	5.5
Stockpile Stewardship (DIRS 103217-DOE 1996, all)	--	38[d]	0.064
Pantex (DIRS 103218-DOE 1996, all)	250[f]	490[d]	0.006
West Valley (DIRS 101729-DOE 1996, all)	1,400	12,000	3.6
S3G and D1G prototype reactor plant disposal (DIRS 103221-DOE 1997, all)	2.9	2.2	0.010
S1C prototype reactor plant disposal (DIRS 103219-DOE 1996, all)	6.7	1.9	0.0037
Container system for Naval spent nuclear fuel (DIRS 101941-USN 1996, all)	11	15	0.045
Cruiser and submarine reactor plant disposal (DIRS 103479-USN 1996, all)	5.8	5.8	0.00095
Submarine reactor compartment disposal (DIRS 103477-USN 1984, all)	--	0.053	NL
Uranium billets (DIRS 103189-DOE 1992, all)	0.50	0.014	0.00056
Nitric acid (DIRS 103212-DOE 1995, all)	0.43	3.1	NL
General radioactive material transportation			
1943 to 2033	310,000	260,000	19
1943 to 2047	330,000	290,000	22
Subtotal of non-repository-related transportation impacts			
1943 to 2033	**330,000**	**310,000**	**94**
1943 to 2047	**350,000**	**340,000**	**97**
Proposed Action			
Mostly legal-weight truck	29,000	5,000	4.5
Mostly rail	7,900 - 8,800	1,200 - 1,600	2.3 - 3.1
Module 1 or 2[g]			
Mostly legal-weight truck	60,000	9,700	8.7
Mostly rail	16,000 - 17,000	2,200 - 3,100	4.2 - 5.9
Total collective dose (total latent cancer fatalities)[h] *and total traffic fatalities*			
Proposed Action			
Mostly legal-weight truck	360,000 (140)	320,000 (160)	98
Mostly rail	340,000 (140)	310,000 (160)	97
Module 1 or 2[g]			
Mostly legal-weight truck	410,000 (160)	350,000 (180)	110
Mostly rail	370,000 (150)	340,000 (170)	100

a. Sources: DIRS 104800-CRWMS M&O (1999, Section 7) except for the Proposed Action and Inventory Module 1 or 2, which are from Table 8-54. All references in this table refer to the original source of information cited in DIRS 104800-CRWMS M&O (1999, Section 7).

b. NL = not listed.

c. -- = reported or included with the general population dose.

d. Includes worker and general population doses.

e. Includes mixed low-level waste and low-level waste; transuranic waste included in DIRS 101814-DOE (1997, Volume 1).

f. Includes all highly enriched uranium shipped to Y-12.

g. The transportation-related radiological collective doses for Inventory Module 1 or 2 include the doses from the Proposed Action (see the definition of Modules 1 and 2 in Section 8.1.2.1).

h. The conversion factors for worker and general population dose to latent cancer fatalities are 0.0004 and 0.0005 latent cancer fatality per person-rem, respectively (DIRS 101856-NCRP 1993, p. 31) occurred in the United States. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

these numbers in perspective, there were 541,532 deaths in the United States during 1998 due to cancer, although the number for any given year understandably fluctuates (DIRS 153066-Murphy 2000, p. 83). This section presents an estimate of latent cancer fatalities slightly greater than 300 over a period of about 100 years (that is, an average of about 3 latent cancer fatalities per year). This value would be indistinguishable from the natural fluctuations in the death rate from cancer.

For transportation accidents involving radioactive material, the dominant risk is due to accidents that are not related to the cargo (traffic or vehicular accidents). Typically, the radiological accident risk (latent cancer fatalities) from transportation accidents is less than 1 percent of the vehicular accident risk (see Table 8-56). In addition, no acute radiological fatalities due to transportation accidents have ever occurred in the United States. Therefore, the number of vehicular accident fatalities was used to quantify the cumulative impacts of transportation accidents.

From 1943 through 2033 an estimated 4 million people would be killed in motor vehicle accidents and 180,000 people would be killed by railroad accidents. From 1943 through 2047, an estimated 4.4 million people would be killed in motor vehicle accidents and 200,000 people would be killed in railroad accidents. Based on the estimated number of traffic fatalities for the reasonably foreseeable actions and for the Proposed Action and Inventory Module 1 or 2 listed in Table 8-58, the transport of radioactive material would contribute about 110 fatalities to these totals.

8.4.2 NEVADA TRANSPORTATION

This section analyzes potential cumulative impacts that Inventory Module 1 or 2 and past, present, and other reasonably foreseeable future Federal, non-Federal, and private actions could have on the construction and operation of a branch rail line or the construction and operation of an intermodal transfer station and associated highway upgrades for heavy-haul trucks in the State of Nevada. The analysis included potential cumulative impacts in the vicinity of the five potential branch rail line corridors, the three potential intermodal transfer station locations, and the five associated potential highway routes for heavy-haul trucks.

With respect to potential cumulative impacts from Inventory Module 1 or 2, there would be no cumulative construction impacts because the need for a new branch rail line or new intermodal transfer station and associated highway upgrades for heavy-haul trucks would not change; that is, whatever DOE would build for the Proposed Action would also serve Module 1 or 2. In addition, because the planned annual shipment rate of spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository would be about the same for Module 1 or 2 and the Proposed Action, the only cumulative operations impacts would result because of the extra 14 years of shipping time required for Module 1 or 2. With this basis, the operation and maintenance of a branch rail line or an intermodal transfer station and associated highway route for heavy-haul trucks were analyzed for potential cumulative impacts from Module 1 or 2.

Land-use and ownership impacts identified in Chapter 6 (Section 6.3) would be avoided or otherwise resolved to implement the Proposed Action. However, additional conflicts associated with continued use of the affected land areas could occur due to shipping operations being excluded 14 years beyond that analyzed in the Proposed Action. DOE expects no cumulative impacts from the extended 14 years of operation for Inventory Module 1 or 2 to air quality; hydrology (surface water and groundwater); biological resources and soils; cultural resources; socioeconomics; noise; aesthetics; and utilities, energy, and materials, the impacts of which were assessed on a per shipment, weekly, or annual basis (see Chapter 6, Section 6.3).

Cumulative impacts from Inventory Module 1 or 2 to occupational and public health and safety are included in the occupational and public health and safety impacts of national transportation in

Section 8.4.1. The operation of an intermodal transfer station for more years under Module 1 or 2 would affect waste management impacts. Because of the additional years of operation, more waste of the same types would be generated than for the Proposed Action. However, the small waste quantities generated for Module 1 or 2 would have a minimal impact to the receiving treatment and disposal facilities. Because there would be no large cumulative impacts for any of the resource areas from Module 1 or 2, disproportionately high and adverse cumulative impacts to minority or low-income populations or to Native Americans would be unlikely.

Other than Inventory Module 1 or 2, one other Federal action and several private actions could have the potential for cumulative impacts with the construction and operation of a new branch rail line or intermodal transfer station and associated highway route for heavy-haul trucks.

One private action that could lead to cumulative impacts with the Carlin rail corridor implementing alternative is by Cortez Gold Mine, Inc., which has an existing Pipeline Project mining operation and processing facility (DIRS 103078-BLM 1996, all), a proposed Pipeline Infiltration Project (DIRS 103081-BLM 1999, all), and a possible Pipeline Southeast Expansion Project (DIRS 103078-BLM 1996, p. 5-7) in the Crescent Valley area of Nevada through which the Carlin branch rail line would pass (see Section 8.1.2.3 and Figure 8-5). Because the Carlin corridor would pass through the general area of these projects, there could be cumulative land-use and ownership impacts that would require mitigation.

The analysis for the Carlin rail corridor represents the maximum impact; other rail corridor implementing alternatives would have smaller impacts. Cumulative impacts for the mostly legal-weight truck scenario would also have smaller impacts.

Another private action that could result in cumulative impacts would be shared use of a branch rail line that DOE constructed and operated to transport spent nuclear fuel and high-level radioactive waste to the Yucca Mountain Repository by others (for example, mine operators, private freight shippers) because of the increased rail traffic. Because predicting the increase in rail traffic is not possible at this time, this analysis cannot estimate the cumulative impacts. There could be some added impacts to all the resource areas beyond those evaluated for the Proposed Action in Chapter 6, but there could also be benefits from the improved economic potential for resource development in interior areas of Nevada as well as greater economic development potential for nearby communities. DOE would have to consider these impacts in any decision it made to allow shared use of the branch rail line.

One Federal action and one private action could lead to cumulative impacts with the construction and operation of the Caliente intermodal transfer station. DOE has specified the Caliente site as one of four possible locations for the construction and operation of an intermodal transfer station for the shipment of low-level radioactive waste to the Nevada Test Site (DIRS 103225-DOE 1998, pp. 2-4 to 2-12). In addition, a commercial venture planned by Apex Bulk Commodities for the Caliente site would construct an intermodal transfer station for the transport of copper concentrate. Figure 8-6 shows a possible layout plan for these intermodal transfer stations at Caliente. Section 8.1 provides more information on the potential DOE and Apex intermodal transfer stations. The following sections describe the potential cumulative impact analysis at the Caliente site from the construction and operation of an intermodal transfer station to support the proposed Yucca Mountain Repository, coupled with an intermodal transfer station for shipment of low-level radioactive waste to the Nevada Test Site and an intermodal transfer station proposed by Apex Bulk Commodities.

8.4.2.1 Land Use and Ownership

Chapter 6, Section 6.1.2.1, discusses reasonably foreseeable actions along the rail corridors and heavy-haul truck routes as they would apply to the Proposed Action. The differences in Module 1 and Module 2 in comparison to the Proposed Action are discussed below.

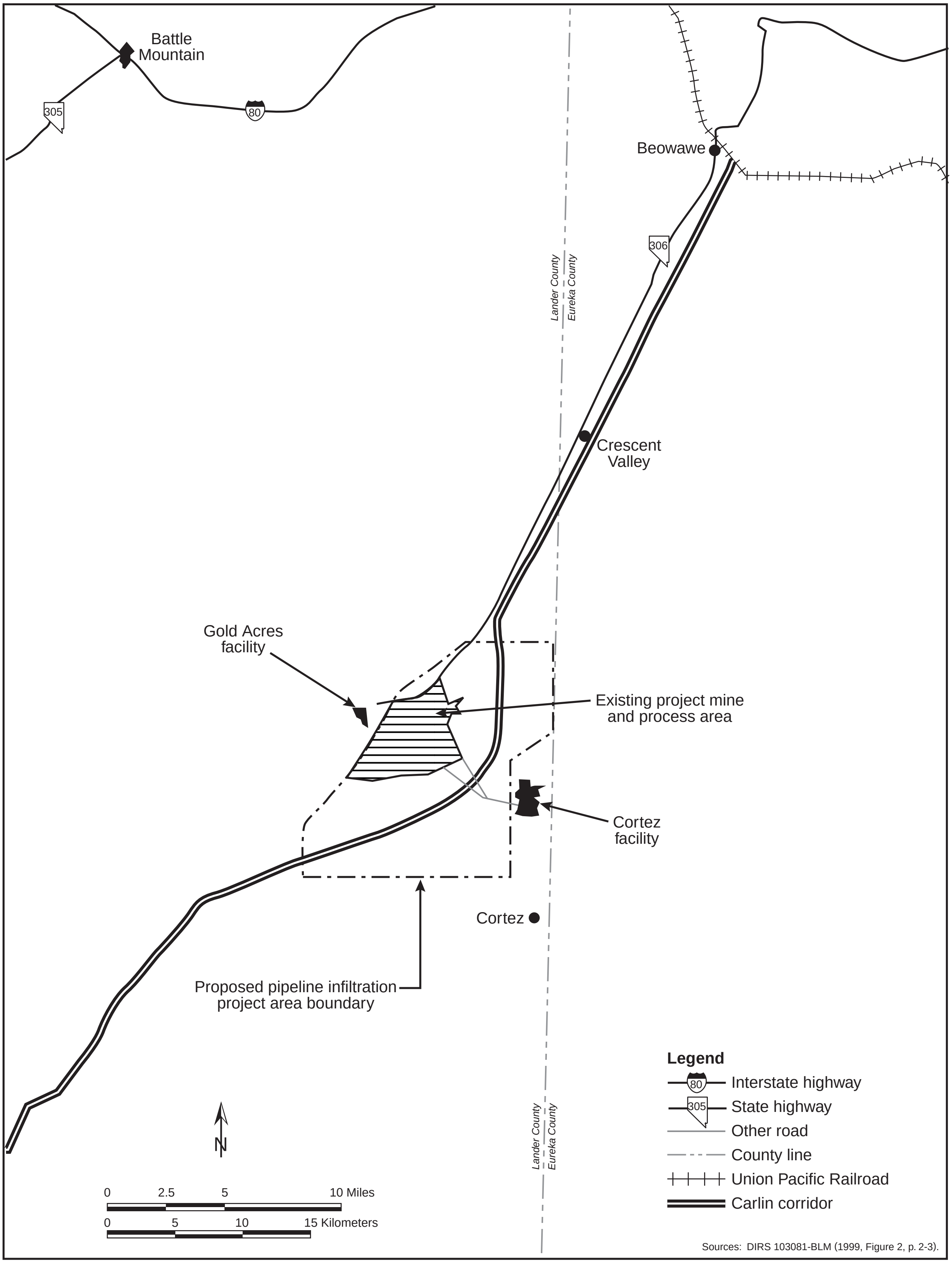

Figure 8-5. Cortez Gold Mine existing pipeline project and proposed pipeline infiltration project.

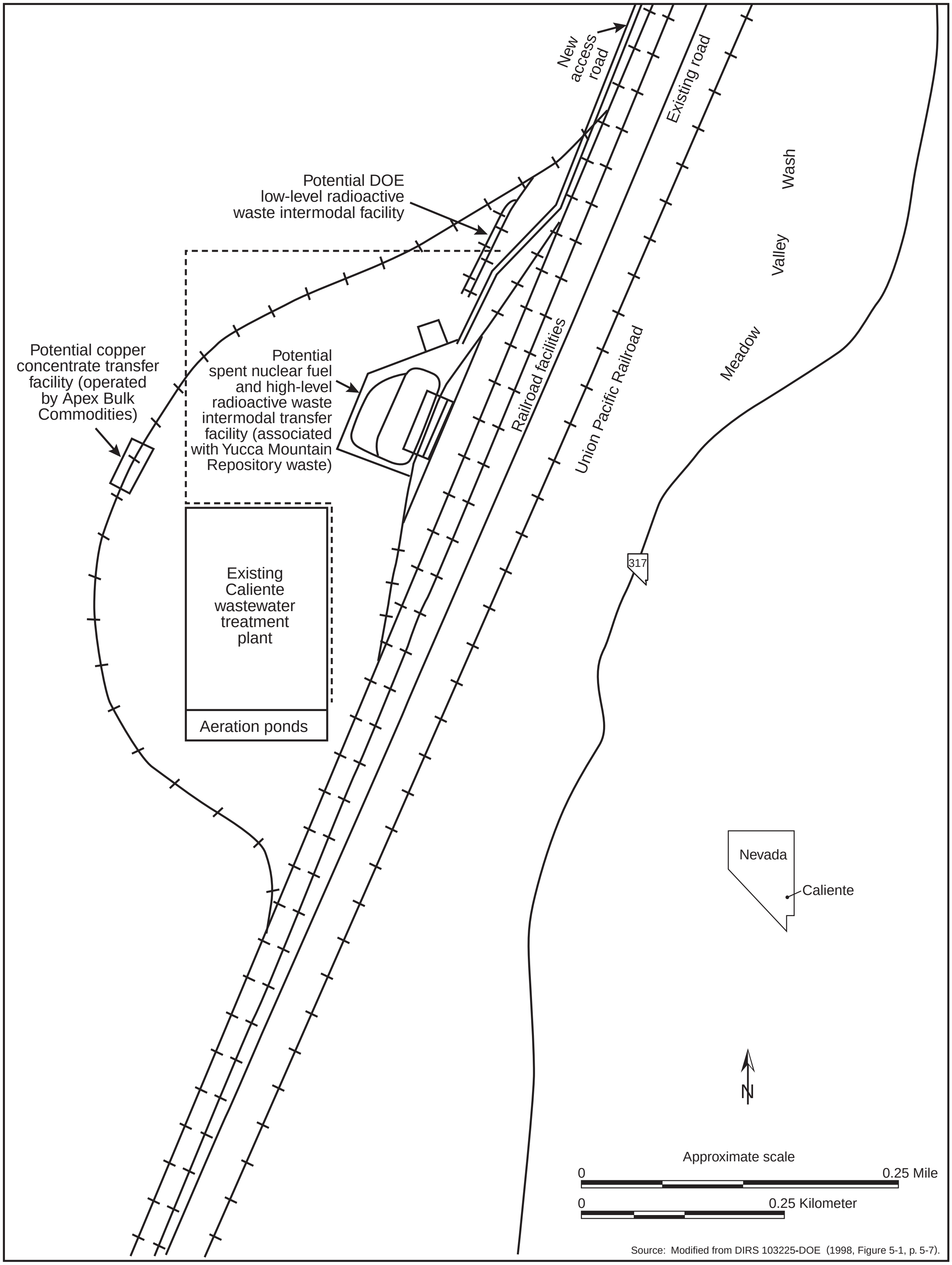

Figure 8-6. Potential locations of intermodal transfer stations at Caliente.

As discussed in Chapter 6, Section 6.3.2.1 there are currently 20 new electric generating plants proposed for the State of Nevada. Of these, 13 are proposed for Clark County in southern Nevada. Currently, plant details are not readily available for a detailed evaluation. However, should these plants be constructed, the rights-of-way necessary for transmission lines and/or natural gas supply lines will most likely be constructed on Bureau of Land Management lands. This would increase the amount of public lands in Nevada that would not be available to other users. Actual impacts associated with the rights-of-way, especially to the candidate rail corridors, would be similar to existing rights-of-way discussed in Section 6.3.2.1.

Section 6.3 of Chapter 6 and Section J.3.1.1 of Appendix J also discuss potential land use and ownership conflicts along candidate rail corridors that could result from the Proposed Action. These include potential conflicts with land areas on the Nellis Air Force Range, Timbisha Shoshone trust land parcel near Scottys Junction, Nevada, planned Ivanpah Valley regional airport, and wilderness study areas. If DOE decided to construct and operate a branch rail line in a rail corridor, it would avoid or mitigate any associated land use and ownership conflicts to implement the Proposed Action. However, additional conflicts associated with continued use of affected land areas could occur due to shipping operations being extended for 14 years beyond that of the Proposed Action.

The land required for the DOE low-level radioactive waste and Apex intermodal transfer stations would add to the approximately 0.21 square kilometer (50 acres) of property that would be required for the intermodal transfer station that would support the proposed Yucca Mountain Repository. The rail spur and facility for the low-level radioactive waste intermodal transfer station would disturb approximately 0.02 square kilometer (5 acres) of land. The Apex transfer facility would be in a building about 90 by 30 meters (300 by 100 feet). In addition, Apex would have a truck maintenance facility in a building about 30 by 18 meters (100 by 60 feet) that it could share with the low-level radioactive waste intermodal facility. The incremental impacts resulting from the changes in land use associated with the three intermodal transfer stations would not result in a substantial cumulative impact.

In addition to the cumulative changes in land use and ownership, DOE considered potential conflicts with plans and policies issued by various government entities along the alternative transportation corridors. In particular, DOE reviewed the Las Vegas 2020 Master Plan (DIRS 157274-City of Las Vegas 2001, all) and various other planning documents, including master plans for the Cities of Caliente (DIRS 157312-Sweetwater and Anderson 1992, all) and Alamo (DIRS 157275-Intertech and Sweetwater 1990, all), and the Lander County Revised Policy for Federally Administered Lands (DIRS 157310-Lander County 1999, all). The Las Vegas Master Plan provides broad policy direction for future land use decisions and related aspects in the City of Las Vegas through 2020. While the Alamo plan deals primarily with zoning issues, the Caliente plan discusses actions for dealing with potential population growth generated by the construction and operation of a repository at Yucca Mountain. The Caliente document generally expresses a need to annex lands that are contiguous to and south of the City in Meadow Valley Wash. The Caliente Intermodal Transfer Facility would be in Meadow Valley Wash (see Chapter 6, Figure 6-17). In general, local government policy indicates a goal of minimizing the conversion of private lands for public use. The transportation corridors and routes described in the EIS, particularly the rail corridors, were developed to minimize impacts to private lands. Section 6.3.2 discusses the amount of private land encountered along the rail corridors and a minimum-to-maximum range for each corridor, including variations and options. However, definitive information is not available on specific tracts of land that could be required for a specific transportation mode or route. Once DOE selected a transportation mode and a specific transportation corridor, more definitive information could be developed on potential conflicts with land uses and various agency plans and policies and, ultimately, the mitigation measures that could be needed to resolve conflicts and impacts on a given area.

8.4.2.2 Air Quality

Air quality cumulative impacts during construction of three intermodal transfer stations—one for intermodal transfers of casks containing spent nuclear fuel and high-level radioactive waste, one for intermodal transfers of low-level radioactive waste shipments to the Nevada Test Site, and one for intermodal transfers of Apex copper concentrate—would not be expected to occur since construction activities would likely occur at different times. The area in which the construction would occur is in attainment of the National Ambient Air Quality Standards and is outside of the Las Vegas Valley particulate matter (PM_{10}) and carbon monoxide nonattainment areas. Even if construction for all three intermodal transfer stations occurred concurrently, administrative controls would be implemented to prevent an adverse impact from collective emissions and dust-generating activities.

Emissions from all sources would be less than applicable standards for repository activities. Emissions would also be below established standards for a mostly legal-weight truck transportation scenario. For a mostly rail scenario, criteria pollutants would be emitted during earthmoving operations for branch rail line or intermodal transfer station and highway upgrade construction projects. Cumulative impacts would be greatest for activities occurring in the Las Vegas air basin, which is currently in nonattainment for particulate matter (PM_{10}) and carbon monoxide. For rail implementing alternatives, emissions into the Las Vegas air basin would exceed emission standards only for construction of a Valley Modified branch rail line. Emission standards could be exceeded by up to 90 percent for PM_{10} and up to 60 percent for carbon monoxide. Emissions from upgrading highways for a Caliente/Las Vegas heavy-haul truck route could also exceed standards for the Las Vegas air basin. PM_{10} emissions could slightly exceed the standard and carbon monoxide emissions could exceed the standard by 10 percent. All other activities would not cause emissions that exceeded emission standards.

During operations, there would be approximately one or two repository rail shipments and as many as 11 associated heavy-haul trucks a week, an average of about three trains and seven trucks a day for DOE low-level radioactive waste shipments, and one truck an hour for the Apex copper concentrate transport. At present, an average of one train an hour and light highway traffic travels through Caliente. The incremental increase in air pollutants from rail and highway traffic resulting from the three actions would cause slight, temporary increases in pollutants, but would not exceed Federal standards (Chapter 6, Section 6.3.2; DIRS 103225-DOE 1998, pp. 4-13, 5-4, and 5-8). Criteria pollutants released during routine operations of the intermodal transfer stations would include nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter. DOE expects these emissions would also be well within Federal standards.

8.4.2.3 Hydrology

Surface Water

Mitigation measures used during the construction of the intermodal transfer stations would minimize surface-water impacts. Floodplain impacts probably would occur if DOE selected the Caliente intermodal transfer station (see Appendix L). If that location was selected, DOE would conduct a detailed floodplain/wetland assessment and integrate good construction practices to minimize impacts. Construction probably would involve some permanent drainage alterations. Runoff rates would differ from natural or existing terrain but, given the relatively small size of the area, there would be little effect on overall runoff quantities for the area (Chapter 6, Section 6.3.3.1; DIRS 103225-DOE 1998, pp. 4-13 and 5-8). DOE expects very small impacts to surface waters during the construction and operation of the stations.

Groundwater

Construction activities for the intermodal transfer stations would disturb and loosen the ground for some time, which could result in higher infiltration rates. However, these activities and their resultant short-term impacts probably would occur at different times for the three stations. The relatively small sizes of the three facilities would minimize changes in groundwater infiltration rates during operations. Potential sources of contamination would include one to three diesel fuel tanks for the standby generators and heavy equipment for all three stations. The small overall water demand could be met by installing wells or by existing water distribution systems. In addition, the operation of the Apex copper concentrate and DOE low-level radioactive waste intermodal transfer station would only overlap with the beginning years of spent nuclear fuel and high-level radioactive waste shipment to the proposed Yucca Mountain Repository.

8.4.2.4 Biological Resources and Soils

The proposed locations of the intermodal transfer stations are in an irrigated pasture area that is partly wetland. However, because the area was modified as pasture and the native habitat has been degraded, cumulative impacts to biological resources would be low. Construction activities could lead to soil erosion. Water would be applied to suppress dust and compact soil. The operation of the stations would have small cumulative impacts on soils. Erosion damage control would be performed as necessary throughout the operational periods.

8.4.2.5 Cultural Resources

Cumulative impacts could occur to archaeological, historic, and traditional Native American cultural sites from the construction of the intermodal transfer stations. Cultural resource surveys of a portion of the Meadow Wash Area have identified two archaeological sites in the vicinity of the proposed Caliente DOE low-level radioactive waste intermodal site (DIRS 103225-DOE 1998, p. 4-13). Neither site falls within the proposed intermodal transfer station areas. However, Native American consultants have identified these archaeological sites as having significant cultural values for present-day Native American tribes, and construction and operation of the intermodal transfer station at this location could create a cumulative impact to these cultural values. DOE would perform ethnographic studies and archaeological surveys during the engineering design phases and before construction to identify these impacts and address their mitigation.

Impacts to cultural resources could occur along each of the candidate rail corridors where site file and literature searches have indicated a potential for archaeological, historic, and traditional cultural properties (see Chapter 3, Section 3.2.2.1.5). Some impacts to these resources could be cumulative, such the intersection of the National Historic Pony Express Trail by variations of the Carlin Corridor or the construction and operation of a branch rail line in Crescent Valley along the Carlin Corridor, where Native Americans believe that operations at the Cortez Mine have already had an impact on a Native American cemetery. After determining the mode of transportation and the preferred routing, DOE would undertake archaeological field studies and ethnographic evaluations of the corridor to identify further potential impacts and possible mitigative actions to reduce the effects of those impacts.

Some impacts associated with the use of existing highways could be cumulative, depending on the route selected. For example, Native American consultants have identified several places or areas along some of the highways that have cultural significance to regional tribes (see Chapter 3, Section 3.2.2.2.5). Heavy-haul truck traffic could have a cumulative adverse effect on the Goldfield National Register Historic District, although the potential for specific impacts to buildings in the historic district has yet to be fully evaluated. As with other potential components of the Nevada transportation scenario, DOE would complete additional archaeological, historical and ethnographic studies during the engineering design phase to identify and evaluate these types of potential impacts.

8.4.2.6 Socioeconomics

Employment levels for operation of the repository, Apex, and DOE low-level radioactive waste intermodal transfer stations would be 66, 25, and 14 employees, respectively (Chapter 6 and Section 8.1.2.2). Employment associated with the repository and low-level radioactive waste intermodal transfer stations includes operations personnel and truck drivers. Concurrent operations for all three stations would occur over a portion of the entire 24- or 38-year shipping period for the Proposed Action or Inventory Module 1 or 2, respectively. Employment levels would increase gradually to the maximum values listed above and then decrease gradually toward the end of emplacement activities for repository-related workers. Impacts to employment, population, personal income, Gross Regional Product, and state and local government expenditures during station operations would be small for Lincoln County (Chapter 6, Section 6.3.2.2; DIRS 103225-DOE 1998, pp. 4-14 and 5-9).

The truck traffic in the Caliente area would be increased from the three intermodal transfer stations. The small increase would have a very small impact on U.S. Highway 93, which would be used when entering and leaving the intermodal transfer station access road. U.S. 93 is currently characterized as having light traffic. The period of concurrent truck traffic from the three intermodal transfer stations would also occur only over a portion of the 24- or 38-year shipping duration for the Proposed Action or Inventory Module 1 or 2, respectively.

8.4.2.7 Occupational and Public Health and Safety

The incremental impacts resulting from an increase in radiological risk associated with the intermodal transfer stations for the repository and low-level radioactive waste shipments at Caliente would not result in a substantial cumulative impact. The estimated total collective worker dose from the entire DOE low-level radioactive waste intermodal shipping campaign, including transportation impacts, would be about 4.21 person-rem (DIRS 103225-DOE 1998, p. 4-10). This dose, added to the total repository intermodal transfer station and rail and heavy-haul truck shipments worker dose of about 2,200 to 3,300 person-rem for the Caliente intermodal transfer station for Inventory Module 1 or 2 (Appendix J, Table J-59) would be an increase of less than 1 percent. The population dose associated with low-level radioactive waste shipments by truck from the Caliente intermodal transfer station would be 7.55 person-rem for the entire shipping campaign (DIRS 103225-DOE 1998, Table C-11, p. C-23). This dose, added to the dose from shipments in Nevada that use heavy-haul trucks of about 600 person-rem over 38 years, would increase the population dose and associated health effects by less than 1 percent.

In addition to incremental impacts resulting from increases in radiological risk, there would be increments in nonradiological impacts of transportation in Nevada that are not included in the national impacts of transporting spent nuclear fuel and high-level radioactive waste to a Yucca Mountain Repository. These increases would arise from 14 additional years of operating a branch rail line or of maintaining highways for use by heavy-haul trucks and operating an intermodal transfer station. The increments in nonradiological impacts for operation of a branch rail line would include increased traffic fatalities from worker commuting and the transportation of spent nuclear fuel and high-level radioactive waste, as well as repository materials. The increases would range from 0.45 to 1.1 fatalities (see Tables 6-78, 6-79, 6-85, 6-86, 6-93, 6-94, J-61, J-62, and J-63).

8.4.2.8 Noise

There would be an increase in noise levels at Caliente from any of the three candidate intermodal transfer station sites and the associated train switching operations and truck traffic. Noise levels would increase during daytime and night hours for rail activities and during daytime hours for truck shipment activities associated with the repository heavy-haul trucks and the DOE low-level radioactive waste trucks. Apex truck shipments would occur once an hour, 24 hours a day. Noise associated with railcar shipments would occur as the railcars were uncoupled from trains and transferred in and out of the stations, which could occur during the day or night. Elevated noise levels would occur during loading and unloading operations and briefly as trucks passed on the highway. Trucks would not travel through Caliente for shipments to either Yucca Mountain or the Nevada Test Site. Overall, the elevation of noise levels associated with rail and truck activity near a level that would cause concern would be unlikely. In addition, due to the location of the intermodal transfer stations in an uninhabited canyon area, noise impacts from rail and truck loading and unloading would be low. Cumulative effects would also be limited because operations at the DOE low-level radioactive waste and Apex intermodal transfer stations would overlap only a portion of the shipping campaign associated with the proposed repository.

Future development of the Timbisha Shoshone Trust Lands parcel near Scottys Junction could result in additional impacts. Residences and commercial ventures located near the transportation corridor on this parcel (the Bonnie Claire variation of the Caliente and Carlin rail corridors) could encounter noise levels that would not exceed 90 dB at 15 meters (49 feet) from the route.

8.4.2.9 Aesthetics

Chapter 6, Section 6.1.2.9 discusses direct impacts from the candidate rail corridors and heavy-haul truck routes. Section 6.3.2 discusses indirect visual impacts as they could affect land use along the rail corridors.

The alteration of the landscape immediately surrounding the Bureau of Land Management Class II lands [within about 8 kilometers (5 miles) of the Kershaw-Ryan State Park] could exceed the Class II objective. In addition, the Wilson Pass Option in the Jean Corridor passes through Class II lands [55 kilometers (34 miles)] in the vicinity of Wilson Pass in the Spring Mountains. Class II designation by the Bureau of Land Management could require retention of the existing character of the landscape. However, the area proposed for the Caliente intermodal transfer station has been classified as Class III, which would require partial retention of the existing character of the landscape. The intermodal facilities would not greatly alter the landscape more than the current passing trains and sewage treatment operations. The Class II lands of the Wilson Pass Option would require retention of the existing character of the landscape. Public exposure would be limited due to obstruction by natural vegetation. Therefore, visual impacts would be very small (DIRS 103225-DOE 1998, pp. 4-12 and 5-8).

8.4.2.10 Utilities, Energy, and Materials

Electric power lines with adequate capacity are available near the site. Electric power, water supply, and sewage disposal facilities are currently provided to the sewage treatment facility near the proposed location of the intermodal transfer stations (DIRS 103225-DOE 1998, p. 4-12). Therefore, cumulative impacts to utilities would be small. The quantities of concrete, asphalt, and steel needed to build the intermodal facilities (associated mostly with the repository intermodal transfer station) would be unlikely to affect the regional supply system.

8.4.2.11 Management of Intermodal Transfer Station-Generated Waste and Hazardous Materials

The expected quantities of sanitary waste, small amounts of hazardous waste, and low-level radioactive waste associated with radiological surveys would be unlikely to have large impacts to landfill, treatment, and disposal facilities available for use by this site. Therefore, cumulative impacts for waste management would be small. Only limited quantities of hazardous materials would be needed for station operations, and DOE does not expect these needs to affect the regional supply system (DIRS 103225-DOE 1998, pp. 4-12, 4-13, and 5-8).

8.4.2.12 Environmental Justice

Because there would be no large cumulative impacts to human health and safety from the construction or operation of the intermodal transfer stations, there would be no disproportionately high and adverse impacts to minority and low-income populations. The absence of large cumulative environmental impacts for the general population means that there would be no disproportionately high and adverse environmental impacts for the minority or low-income communities. An evaluation of subsistence lifestyles and cultural values confirms these general conclusions. The foregoing conclusions and evaluations and the commitment by DOE to ensure minimal impacts to cultural resources show that construction and operation of the intermodal transfer stations would not be expected to cause or contribute to disproportionately high and adverse impacts to Native Americans (DIRS 103225-DOE 1998; pp. 4-14 and 5-9).

8.5 Cumulative Manufacturing Impacts

This section describes potential cumulative environmental impacts from the manufacturing of the repository components required to emplace Inventory Module 1 or 2 in the proposed Yucca Mountain Repository. No adverse cumulative impacts from other Federal, non-Federal, or private actions have been identified because no actions have been identified that, when combined with the Proposed Action or Inventory Module 1 or 2, would exceed the capacity of existing manufacturing facilities.

The overall approach and analytical methods and the baseline data used for the evaluation of cumulative manufacturing impacts for Inventory Module 1 or 2 were the same as those discussed in Chapter 4, Section 4.1.15 for the Proposed Action. The evaluation focused on ways in which the manufacturing of the repository components could affect environmental resources at a representative manufacturing site and potential impacts to material sources and supplies.

Table 8-59 lists the total number of repository components required for the Proposed Action and Inventory Modules 1 and 2. As listed, the total number would increase by approximately 30 to 50 percent for Modules 1 and 2 in comparison to the Proposed Action depending on the operating mode and packaging scenario. The highest total number of repository components would be for Module 2, assuming the lower-temperature operating mode using derated waste packages, and this was the number used in the cumulative impact analysis.

Based on the total number of components that would be required over a 38-year period for Inventory Module 1 or 2, the annual manufacturing rate would remain the same as that for the Proposed Action.

Based on the number of drip shields required over a 12-year period for Inventory Module 1 or 2, the annual manufacturing rate would increase about 30 percent over that for the Proposed Action 10-year drip shield manufacturing period.

Thus, the annual Module 1 or 2 impacts for air quality, socioeconomics, material use, and waste generation would be as much as 30 percent higher than those for drip shield manufacturing discussed in Chapter 4, Section 4.1.15 for the Proposed Action, and these impacts would continue for 12 years rather than the 10 years for the Proposed Action. The total number of worker injuries and illness or fatalities would increase in proportion to the increase in components manufactured. The potential number of injuries and illnesses over the entire 50-year period for Module 1 or 2 would be from 930 to 1,300 and the estimated number of fatalities would be 0.44 to 0.63 (that is, no expected fatalities), depending on the operating mode and packaging scenario. As for the Proposed Action, there would be few or no impacts on other resources because existing manufacturing facilities would meet the projected manufacturing needs and new construction would not be necessary and environmental justice impacts (that is, disproportionately high and adverse impacts to minority or low-income populations) would be unlikely.

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Table 8-59. Number of offsite-manufactured components required for the Proposed Action and Inventory Modules 1 and 2.

		Operating mode/packaging scenario								
		Proposed Action			Module 1			Module 2		
		UC	C	UC/C[a]	UC	C	UC/C[a]	UC	C	UC/C[a]
Component	Description	HT		LT	HT		LT	HT		LT
Disposal containers	Containers for disposal of SNF[a] and HLW[a]	11,300	11,300	11,300 - 16,900	16,650	16,650	16,650 - 25,350	17,250	17,250	17,250 - 26,000
Rail shipping casks or overpacks	Storage and shipment of SNF and HLW	0	120	0 - 120	0	152	0 - 197	0	157	0 - 202
Legal-weight truck shipping casks	Storage and shipment of uncanistered fuel	120	8	8 - 120	227	13	13 - 227	241	13	13 - 241
Drip shields	Titanium cover for a waste package	10,500	10,500	11,300 - 15,900	15,600	15,600	16,650 - 23,400	16,300	16,300	17,250 - 24,700
Emplacement pallet	Support for emplaced waste package	11,300	11,300	11,300 - 16,900	16,650	16,650	16,650 - 25,350	17,250	17,250	17,250 - 26,000
Solar panels[b]	Photovoltaic solar panels–commercial units	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Dry storage cask shells[c]	Metal shell structure of storage vault for aging	0	0	0 - 4,000	0	0	0 - 4,000	0	0	0 - 4,000

a. UC = uncanistered packaging scenario; C = canistered; HT = higher-temperature operating mode; LT = lower-temperature operating mode; SNF = spent nuclear fuel; HLW = high-level radioactive waste.

b. Number of panels in use at any one time.

c. Necessary only if DOE used surface aging as part of a lower-temperature operating mode.

8.6 Summary of Cumulative Impacts

As shown throughout Chapter 8, DOE has examined many actions in the region to determine the potential for cumulative impacts. These impacts could arise from a variety of sources, including other activities in the area and reasonably foreseeable activities.

Table 8-60 summarizes cumulative impacts from all origins. Where qualitative descriptions are more meaningful, these have been included in lieu of quantitative values, although the quantitative values might be provided in this chapter. In other cases, the quantitative values have been provided to give a better representation of the potential impacts.

Table 8-60. Summary of cumulative impacts presented in Chapter 8 (page 1 of 2).

Discipline area	Cumulative impact
Land use and ownership	About 600 square kilometers (150,000 acres) of land would be withdrawn for the repository, but land is already under Federal control. Other actions in the area would cause additional withdrawals, but some land would also be returned under the Southern Nevada Public Land Management Act. Overall, total land withdrawal analyzed in this EIS is less than 0.5 percent of total Federal lands in Nevada.
Air quality	*Nonradiological:* Emissions from all sources would be less than applicable standards for repository activities. Emissions would also be below established standards for a mostly legal-weight truck transportation scenario. For a mostly rail scenario, criteria pollutants would be emitted during earthmoving operations for branch rail line or intermodal transfer station and highway upgrade construction projects. Cumulative impacts would be greatest for activities occurring in the Las Vegas air basin, which is currently in nonattainment for particulate matter (PM_{10}) and carbon monoxide. For rail implementing alternatives, emissions into the Las Vegas air basin would exceed emission standards only for construction of a Valley Modified branch rail line. Emission standards could be exceeded by up to 90 percent for PM_{10} and up to 60 percent for carbon monoxide. Emissions from upgrading highways for a Caliente/Las Vegas heavy-haul truck route could also exceed standards for the Las Vegas air basin. PM_{10} emissions could slightly exceed the standard and carbon monoxide could exceed the standard by 10 percent. All other activities would not cause emissions that exceeded emission standards.
	Radiological: Short-term air emissions from nearby facilities would result in a dose to the maximally exposed individual of no greater than 2.5 millirem per year. Emissions from past nuclear weapons testing could have resulted in a dose of 150 millirem over the lifetime of those individuals exposed during atmospheric weapons testing. Long-term atmospheric releases from the Nevada Test Site and Beatty Low-Level Waste Facility are not expected to result in a dose greater than 0.007 millirem per year in the future.
Hydrology	*Surface Water:* Cumulative impacts on surface water quality are not expected because of the transient nature of the surface water bodies around the repository. Minor changes to runoff and infiltration rates could occur. Construction of access routes at the repository site could have minor and localized effects on several washes at Yucca Mountain. Elsewhere in Nevada, routes being considered for the movement of waste to Yucca Mountain would pass through or near floodplains and wetlands and would be assessed in more detail once a route is selected.
	Groundwater: Groundwater demands from the repository are below the perennial yield of the western two-thirds of the Jackass Flats basin. When combined with Nevada Test Site activities, the annual water withdrawal (600 acre-feet) could exceed the lowest estimate of perennial yield but would not exceed highest estimate of perennial yield. No short-term impacts to groundwater quality are expected. Long-term impacts to groundwater could be as high as 0.007 millirem per year under the conservative assumption that impacts from the Nevada Test Site and the repository overlap spatially and chronologically.
Biological resources and soils	Disturbance of desert tortoise habitat would occur. Wildlife would be displaced as a result of repository and transportation activities that used additional land in the region. Little or no loss of wetland habitat is expected. No expected impacts to any species.
Cultural resources	Adverse impacts to cultural resources are not expected. Potential for encountering cultural resources exists along transportation corridors. DOE would use practices to avoid or mitigate adverse impacts in these areas.
Socioeconomics	As many as 3,400 direct jobs during peak employment year from repository activities. Intermodal transfer station or rail line in Lincoln County could change employment estimates by 5 percent.

Table 8-60. Summary of cumulative impacts presented in Chapter 8 (page 2 of 2).

Discipline area	Cumulative impact
Occupational and public health and safety	*Nonradiological:* Repository activities, including transportation, could result in up to 37 fatalities[a] from construction to closure of the repository. *Radiological:* Radiation exposure could result in up to 32 latent cancer fatalities[a] to workers. Short-term radiation exposure to the public could result in up to 5 latent cancer fatalities[a] in the population. Short-term radiation exposure to the maximally exposed individual could cause an increased cancer risk of about 1.2×10^{-6}. Emissions from past nuclear weapons testing could have caused an increased risk of about 7.5×10^{-5} for affected individuals. Long-term releases from the repository and other actions in the area could cause an increased risk of fatal cancer in the future of 0.000006 over the lifetime of an exposed individual.
Noise	Noise levels would be transient and would not be expected to cause adverse impacts for repository operation. Future development of the Timbisha Shoshone Trust Lands near Scottys Junction could result in residents of that parcel being subjected to transient noise from a candidate rail corridor through the parcel.
Aesthetics	Placement of exhaust stacks on top of Yucca Mountain could impact visual resources because stacks would be visible from some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Disturbed areas would be likely on former Federal lands that are used for commercial and private purposes. Acquisition of private lands by the Federal Government could result in reduced aesthetics impacts and possible return of land to natural state.
Utilities, energy, materials, and site services	Peak electrical power demand would require upgrade to electrical transmission and distribution system. Other site systems and nearby suppliers of materials would be sufficient to meet repository and transportation needs. Construction of electrical generating facilities in the region surrounding the repository would increase the electrical generating capacity for the area.
Waste management	If nonradioactive, nonhazardous solid waste was disposed of at the Nevada Test Site, existing landfills would need to be expanded. Other waste types could be disposed of at nearby facilities without exceeding capacities of those facilities.
Environmental justice	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for repository, transportation, or other activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the proposed repository, and that implementing the Proposed Action would continue restrictions on access to the proposed site.

a. These values represent the maximum for each environmental resource area. Because the maximum could occur for different implementing alternatives in the various resource areas, simple addition of these maximums could overstate the impacts due to mixing of incompatible alternatives.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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Table 8-60. Summary of cumulative impacts presented in Chapter 8 (page 2 of 2).

Discipline area	Cumulative impact
Occupational and public health and safety	*Nonradiological:* Repository activities, including transportation, could result in up to 37 fatalities[a] from construction to closure of the repository. *Radiological:* Radiation exposure could result in up to 32 latent cancer fatalities[a] to workers. Short-term radiation exposure to the public could result in up to 5 latent cancer fatalities[a] in the population. Short-term radiation exposure to the maximally exposed individual could cause an increased cancer risk of about 1.2×10^{-6}. Emissions from past nuclear weapons testing could have caused an increased risk of about 7.5×10^{-5} for affected individuals. Long-term releases from the repository and other actions in the area could cause an increased risk of fatal cancer in the future of 0.000006 over the lifetime of an exposed individual.
Noise	Noise levels would be transient and would not be expected to cause adverse impacts for repository operation. Future development of the Timbisha Shoshone Trust Lands near Scottys Junction could result in residents of that parcel being subjected to transient noise from a candidate rail corridor through the parcel.
Aesthetics	Placement of exhaust stacks on top of Yucca Mountain could impact visual resources because stacks would be visible from some distance. If the stacks were equipped with beacons, the visual effect would be more noticeable at night. Disturbed areas would be likely on former Federal lands that are used for commercial and private purposes. Acquisition of private lands by the Federal Government could result in reduced aesthetics impacts and possible return of land to natural state.
Utilities, energy, materials, and site services	Peak electrical power demand would require upgrade to electrical transmission and distribution system. Other site systems and nearby suppliers of materials would be sufficient to meet repository and transportation needs. Construction of electrical generating facilities in the region surrounding the repository would increase the electrical generating capacity for the area.
Waste management	If nonradioactive, nonhazardous solid waste was disposed of at the Nevada Test Site, existing landfills would need to be expanded. Other waste types could be disposed of at nearby facilities without exceeding capacities of those facilities.
Environmental justice	No disproportionately high and adverse cumulative impacts to minority or low-income populations would occur for repository, transportation, or other activities. DOE recognizes that Native American people living in the region near Yucca Mountain have concerns about the protection of traditions and the spiritual integrity of the land that extend to the propriety of the proposed repository, and that implementing the Proposed Action would continue restrictions on access to the proposed site.

a. These values represent the maximum for each environmental resource area. Because the maximum could occur for different implementing alternatives in the various resource areas, simple addition of these maximums could overstate the impacts due to mixing of incompatible alternatives.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

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9. MANAGEMENT ACTIONS TO MITIGATE POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS

This chapter describes management actions that the U.S. Department of Energy (DOE or the Department) is considering to reduce or mitigate adverse impacts to the environment that could occur if the Department implemented the Proposed Action to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. In keeping with previous chapters in this environmental impact statement (EIS), this chapter contains separate discussions for the mitigation of repository impacts and the mitigation of impacts from transportation activities. Mitigation includes activities that (1) avoid the impact altogether by not taking a certain action or parts of an action; (2) minimize impacts by limiting the degree or magnitude of the action and its implementation; (3) repair, rehabilitate, or restore the affected environment; (4) reduce or eliminate impacts over time by preservation or maintenance operations during the life of the action; or (5) compensate for the impact by replacing or substituting resources or environments.

This chapter also describes mitigations in environmental resource areas where DOE has identified adverse impacts and analysis has indicated that mitigation has the potential to reduce those impacts. This chapter does not discuss mitigations for environmental resource areas for which analyses have not identified a potential for impacts.

Changes in repository design have resulted in modifications to some planned or potential mitigation measures identified in the Draft EIS. In addition, DOE has identified some new mitigation measures.

Apart from the impact findings and mitigations discussed in this EIS, Section 116(c) of the Nuclear Waste Policy Act, as amended (NWPA) states that "the Secretary shall provide financial and technical assistance to (an affected unit of local government or the State of Nevada)… to mitigate the impact on such (an affected unit of local government or the State of Nevada) of the development of (a) repository and the characterization of (the Yucca Mountain) site." Such assistance can be given to mitigate likely "economic, social, public health and safety, and environmental impacts." Within that broad framework, neither Section 116 nor any other provision of the NWPA limits the impacts that are subject to assistance under Section 116 to the environmental impacts considered in this EIS.

The fact that the EIS analysis has determined that the implementation of the Proposed Action would not cause substantial socioeconomic impacts to communities in Nevada or to the State of Nevada does not prevent local governments or the State government from receiving assistance to address economic, social, public health, or environmental impacts under Section 116(c).

The Section 116 impact assistance review process and the Yucca Mountain Repository EIS process are distinct from one another, and the implementation of one would not depend on the implementation of the other. The provision of assistance under Section 116 would not necessarily be limited either by the impacts identified in this EIS or by its findings on such impacts. Any decision to provide assistance under Section 116 will be based on an evaluation of a report submitted by an affected unit of local government or the State of Nevada pursuant to Section 116 to document likely economic, social, public health and safety, and environmental impacts.

9.1 Types of Management Actions

The design, construction, operation and monitoring, and closure planning for the proposed repository incorporate physical features, procedures, and safeguards to reduce environmental consequences. Some of these features, procedures, and safeguards are the result of DOE determinations based on site characterization activities and the ongoing evaluation of planning and design for the proposed repository.

To complement the measures already incorporated, DOE is considering a range of additional mitigation measures aimed at reducing consequences of the proposed repository project. The repository and transportation mitigation analyses in this chapter discuss impact reduction measures that DOE expects to implement as well as other mitigations DOE is considering.

9.1.1 DOE-DETERMINED IMPACT REDUCTION FEATURES, PROCEDURES, AND SAFEGUARDS

DOE has studied the Yucca Mountain site, vicinity, and regions of influence for more than a decade and has accumulated considerable knowledge. The Department has identified many improvements in its project design and plan to reduce potential impacts. The Proposed Action includes commitments to reduce impacts that DOE has made as a result of its site characterization studies and the ongoing evaluation of repository planning and design. DOE would undertake these measures if the Secretary of Energy recommended the site for development and authorization was provided to proceed with the Proposed Action. This chapter identifies these commitments in appropriate areas.

9.1.2 MITIGATION MEASURES UNDER CONSIDERATION FOR INCLUSION IN PROJECT PLAN AND DESIGN

DOE has conducted extensive site characterization studies, and continues to evaluate whether to commit to additional mitigation measures in the event the site is designated and the Nuclear Regulatory Commission grants a license for the repository project. DOE is considering these additional measures to reduce the potential effects of the repository project. This chapter identifies measures under consideration in appropriate subject areas.

9.1.3 ONGOING STUDIES THAT COULD INFLUENCE MITIGATION MEASURES IN THE PROJECT PLAN AND DESIGN

Accelerator Transmutation of Waste technology has been under consideration for many years as a process for the treatment of nuclear waste. This technology would involve the use of a chemical separation process, a linear accelerator, and a subcritical nuclear assembly. The chemical process would separate transuranic and certain long-lived radioisotopes from the spent nuclear fuel. The linear accelerator and subcritical nuclear assembly would change the transuranic and long-lived radioisotopes into short-lived radioisotopes and stable (nonradioactive) elements.

The National Research Council studied Accelerator Transmutation of Waste and other technologies for use in the treatment of spent nuclear fuel (DIRS 103403-National Research Council 1996, all). The study concluded that:

- The use of separation and transmutation to treat spent nuclear fuel is technically feasible.
- Treatment would cost many tens of billions of dollars and require many decades to implement.
- While other technologies would be based on considerable experience, Accelerator Transmutation of Waste technology would require extensive development before DOE could realistically assess its technical feasibility.
- No separation and transmutation technology offers sufficient promise to abandon current spent nuclear fuel management programs or delay the opening of the first nuclear waste repository.
- Even with a successful separation and transmutation program, a monitored geologic repository would still be necessary because the process would be unlikely to provide perfect transmutation, in which

case there would be residual materials requiring long-term isolation from human populations and concentrations of human activity.

- Separation and transmutation technology might delay or eliminate the need for a second repository, but there are legislative and less expensive technical ways to increase the capacity of the first repository by an equivalent amount.

In the Fiscal Year 1999 Energy and Water Appropriation Act, Congress directed DOE to conduct an Accelerator Transmutation of Waste study and to prepare a plan for the development of this technology in Fiscal Year 1999. In October 1999, DOE submitted to Congress *A Roadmap for Developing Accelerator Transmutation of Waste (ATW) Technology* (DIRS 110625-DOE 1999, all). Key elements of the report include:

- The identification of technical issues requiring resolution
- The delineation of a 6-year science-based program to begin addressing resolution of technical issues
- If technical issues are resolved, a research and development plan for construction of a demonstration facility to become operational in 2035
- If research and development are successful, a production plan for transmutation of 79,000 metric tons (87,000 tons) of civilian waste over 90 years
- A listing of possible collaborative efforts with other countries
- The identification of institutional challenges of an Accelerator Transmutation of Waste program
- A discussion of possible benefits to other programs
- An estimate of the life-cycle costs for transmutation and processing of the currently projected inventory of civilian spent nuclear fuel

The report conclusions include the following:

- The implementation of Accelerator Transmutation of Waste technology will require years of additional research.
- The implementation of Accelerator Transmutation of Waste technology would require a significant investment in research and development funding.
- Accelerator Transmutation of Waste is technically feasible, but it would require billions of dollars and many decades to fully construct and operate a transmutation facility, and it would not eliminate the need for a repository.
- Complex institutional and public acceptance issues regarding the technology would have to be resolved.

A successful Accelerator Transmutation of Waste program would last approximately 117 years and would cost at least $281 billion dollars. Such a program could reduce the radioactivity of commercial waste by a factor of 10 to 100.

Since the October 1999 publication of the Accelerator Transmutation of Waste Roadmap, DOE's transmutation research and development program has undergone significant changes. It is currently managed as an Advanced Accelerator Applications program, with the goal of evaluating the technical feasibility of nuclear waste transmutation using a broader technology base than was covered by the earlier Roadmap. A general description of the modified program was presented in *The Advanced Accelerator Applications Program Plan* on March 30, 2001 (DIRS 156711-DOE 2001, all).

Among other aspects of the program, the plan discusses the proposed design and operation of an Accelerator Driven Test Facility as part of a research and development program that would evaluate combinations of critical and subcritical transmutation systems. These have the potential for utilizing the strengths of each transmutation technology in combination, the effectiveness of which is expected to be greater than either taken separately. A revised roadmap describing the program's new directions is currently being prepared.

The elimination or reduction of certain radionuclides in the disposal inventory could add flexibility to the design of the repository and reduce uncertainties about its performance. DOE will incorporate information from any future studies in its decisions during the preparation of a Mitigation Action Plan for this EIS and during the repository licensing process, if those became necessary.

9.1.4 MITIGATION ACTION PLAN

To minimize potential impacts from the Proposed Action (if the repository site was designated), DOE is evaluating the preparation of a Mitigation Action Plan containing specific commitments for mitigating adverse environmental impacts associated with the Proposed Action. The plan would describe specific actions DOE would take to implement mitigation commitments and would reflect available information about the course of action. DOE could revise this Plan as more specific and detailed information became available.

The Mitigation Action Plan would incorporate all practicable measures to avoid or minimize adverse environmental and human health impacts that could result from the implementation of the Proposed Action. The Plan would contain:

1. An introduction describing the basis, function, and organization of the Plan
2. A summary of the impacts to be mitigated
3. A statement of mitigation goals, objectives, and performance standards
4. A description of specific mitigation actions
5. A description of the Mitigation Action Plan monitoring and reporting system that DOE would implement to ensure that elements of the Plan were met

Precise mitigation measures cannot be identified at present. For example, transportation route selection decisions would affect the potential for impacts to areas of importance to Native Americans, to local communities, or to the general environment; repository or transportation corridor construction activities could reveal new cultural resource sites. DOE would consult with Native American tribes and local governments in developing the Mitigation Action Plan. If activities associated with the Proposed Action could affect specific sacred or ceremonial areas or resources or other areas of importance, DOE could develop procedures for controlled access as long as project integrity was not compromised.

DOE would prepare the Mitigation Action Plan in compliance with applicable regulations. The Plan would accompany any License Application to the Nuclear Regulatory Commission.

9.1.5 MONITORING

DOE would conduct the following monitoring activities during all phases of the project to ensure the implementation of the Proposed Action as described and to ensure mitigation of impacts:

- Continue the performance confirmation program which consists of tests, experiments, and analyses, during all phases of the repository project to evaluate the accuracy and adequacy of the information it used to determine with reasonable assurance that the repository would meet the performance objective for the period after permanent closure.
- Monitor groundwater quality, air emissions, and the repository workplace to ensure project worker safety and other aspects of project interaction with the natural and human environment during the construction, operation and monitoring, and closure phases of the project.
- Conduct cultural resources monitoring activities as appropriate before and during surface disturbance activities to identify and assess the potential for impacts to previously unidentified archaeological resources.
- Conduct monitoring and reporting activities to ensure the implementation and effectiveness of mitigation measures and to ensure in general the accomplishment of the elements of the Mitigation Action Plan.
- Monitor material emplaced in the repository starting with the first emplacement of waste packages and continuing through closure.
- After the completion of emplacement, continue to monitor and inspect waste packages and continue performance confirmation activities.
- After sealing the repository openings, conduct postclosure monitoring to ensure acceptable repository performance. Details of this program would be defined during processing of the license amendment for repository closure rather than now to take advantage of appropriate technology, including technology that might not be currently available.

9.2 Yucca Mountain Repository

This section discusses mitigation measures DOE has determined it would implement, or has identified for consideration, to reduce potential impacts from the construction, operation and monitoring, and eventual closure of the proposed repository.

9.2.1 LAND USE

The Yucca Mountain site is remote and is partly withdrawn for specific Federal uses. The permanent withdrawal of land for the repository would prevent public use of the withdrawn lands for other purposes.

Land Use Measures Under the Proposed Action

- Reclaim lands disturbed during the construction process and not required for permanent use by the repository and surface support facilities.

9.2.2 AIR QUALITY

Construction and operation activities such as vehicle movement, clearing, grading, rock pile maintenance, and excavating could generate substantial quantities of fugitive dust. Standard mitigation measures could reduce dust emissions from fugitive dust-generating activities at the Yucca Mountain site. Other dust-generating sources such as operation of the concrete batch plant and backfill preparation facilities would be comparatively small contributors. DOE expects concentrations of other criteria pollutants to be less than 1 percent of regulatory limits (see Chapter 4, Section 4.1.2). Activities that would generate other criteria pollutants include the operation of internal combustion engines in construction equipment, boiler operation, and similar devices, along with limited emissions of radionuclides.

Air Quality Measures Under the Proposed Action

- Reduce fugitive dust emissions using standard dust control measures routinely applied during construction projects including, for example, routine watering of unpaved surfaces; wet suppression for material storage, handling, and transfer operations; and wind fences to control windblown dust. The efficiency of these controls tends to vary depending on site characteristics, but it ranges from a 60- to 80-percent reduction in fugitive dust emissions (DIRS 103676-Cowherd, Muleski, and Kinsey 1988, p. 5-22).

- Reduce maximum fugitive dust concentrations with working controls such as scheduling construction operations to minimize concurrent generation by activities that were near each other (for example, conducting adjacent clearing and grading activities at different times).

- High-efficiency particulate air filters and modern facility design to minimize the potential for airborne contamination.

9.2.3 HYDROLOGY

This section describes potential mitigation measures for surface water and groundwater.

9.2.3.1 Surface Water

Potential impacts to surface water from the construction, operation and monitoring, and eventual closure of the proposed repository would fall into the following categories: (1) introduction of contaminants, (2) alteration of drainage either by changing infiltration and runoff rates or channel courses, and (3) flood hazards. Changes in infiltration and runoff rates could alter flow rates in channels, cause ponding, and increase erosion. DOE expects such impacts to be minimal (see Chapter 4, Section 4.1.3). Nevertheless, the mitigation of impacts could produce such benefits as erosion control and pollution prevention.

Flash floods could spread contamination from accidental spills. Design and operational controls could mitigate the potential for contamination of surface water from accidental releases of radiological or hazardous constituents. DOE's intent would be to respond rapidly with appropriate cleanup actions.

Surface-Water Measures Under the Proposed Action

- Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates.

- Mitigate flood hazards by designing facilities to withstand or accommodate a 100-year flood, and by designing facilities that would manage radiological materials to withstand the calculated probable maximum flood.

- Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. Use erosion and runoff control features such as proper placement of pipe, grading, and use of rip-rap at these intersections to enhance the effectiveness of the bridges or culverts.

- Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion.

- In and near floodplains, follow reclamation guidelines (DIRS 102188-YMP 1995, all) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance.

- Implement best management practices, including training employees in the handling, storage, distribution, and use of hazardous materials, to provide practical prevention and control of potential contamination sources.

- Conduct fueling operations and store hazardous materials and other chemicals in bermed areas away from floodplains to decrease the probability of an inadvertent spill reaching the floodplains.

- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.

- Use sediment-trapping devices such as hay or straw bales, fabric fences, and devices to control water flow and discharge to trap sediments moved by runoff.

Surface-Water Measures Under Consideration

- Use physical controls such as secondary containment for fuel storage tanks to reduce the potential for releases to mingle with stormwater runoff.

9.2.3.2 Groundwater

Impacts to groundwater from the proposed repository could include introduction of contaminants and alteration of infiltration and runoff rates that could change the rate of recharge to the aquifer. Design and operational actions to reduce such impacts for the active life of the repository and the alteration of infiltration and runoff rates would be identical to those described above for surface-water impacts.

The purpose of proposing a monitored geologic repository is to provide a natural setting that, with engineered repository and waste package barriers, would provide long-term confinement and isolation of spent nuclear fuel and high-level radioactive waste. Two aspects of groundwater analysis—(1) the ability of the repository and the engineered barriers to keep waste packages isolated from groundwater over time, and (2) the extent to which groundwater could become contaminated with radionuclides from breached waste packages and transport radionuclides to places where human exposure could occur—are central elements in determining the potential for a proposed repository to succeed.

DOE's detailed study of the Yucca Mountain site has resulted in the inclusion of many engineered barrier elements to complement the site's natural characteristics to keep unsaturated zone groundwater from reaching and transporting radionuclides and, thereby, to reduce the long-term potential for impacts. The following summarizes the engineered barrier elements that would contribute to a reduction of the long-term potential for impacts from radionuclides isolated in a Yucca Mountain Repository.

Groundwater Measures Under the Proposed Action

- The Yucca Mountain site has several characteristics (as described in Chapter 3) that indicate a high potential for reducing possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste, including:
  - The Yucca Mountain vicinity is isolated from concentrations of human population and human activity and is likely to remain so.
  - The climate is arid and conducive to evapotranspiration, resulting in a relatively small volume of water that has the capability to move as groundwater within the unsaturated zone of the mountain.
  - The groundwater table is substantially below the level at which DOE would locate a repository, providing additional separation from materials emplaced in waste packages.
  - The sparsely populated hydrogeologic basin into which groundwater from Yucca Mountain flows is closed, providing a barrier to a general spread of radionuclides in the event waste packages were breached and radionuclides reached groundwater.
- Use performance confirmation measures to detect any departure from expected capability of the repository in confining and isolating waste.
- Recycle water collected in subsurface areas for use in dust suppression and other activities, to minimize water consumption.
- Implement measures to minimize the potential for water used during operations to interfere with waste isolation in the repository.
- Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates.
- Use corrosion-resistant waste packages and other engineered barriers, such as drip shields, to prevent water intrusion.
- Monitor to detect and define unanticipated spills, releases, or similar events.
- Evaluate scenarios to minimize the potential for different heat levels to have a direct effect on corrosion rates and the integrity of containers, as well as on the hydrology, geochemistry, and stability of the drifts. High levels could indirectly affect general groundwater flow and the transport of radionuclides.
- Use stainless-steel-lined concrete basins that include leak detection systems, pool cleanup equipment, and transfer equipment capable of moving waste in the event of a leak, and that are designed to seismic standards to minimize the potential for leaks in fuel transfer and holding pools located inside surface facilities.
- Use drip shields to deflect water migrating downward through the unsaturated zone to waste emplacement areas.

9.2.4 BIOLOGICAL RESOURCES AND SOILS

Potential impacts to biological resources and soils from repository construction, operation and monitoring, and closure could result from land clearing, vehicle movement, materials placement, trenching and excavation, and accidents. This section discusses the potential mitigation of impacts that could affect the desert tortoise and biological resources and soils in general.

9.2.4.1 Desert Tortoise

The desert tortoise is the only Federally protected species that resides on the site of the proposed repository (see Chapter 3, biology sections). Activities that could cause impacts to desert tortoises include site clearing, vehicle traffic, pond management, and taking of habitat. Since 1990, DOE has been conducting site characterization activities in accordance with Fish and Wildlife Service biological opinions on the potential for impacts to desert tortoises (DIRS 104618-Buchanan 1997, pp. 1 and 2). During these activities, five desert tortoises are known to have been killed by site characterization activities, all by vehicle traffic. A recent report (DIRS 103194-CRWMS M&O 1998, p. 9) indicates that 27 of 28 tortoise relocations were successful and that two nest relocations were also successful. The one unsuccessful relocation involved a tortoise that returned to the area of disturbance and became one of those killed by traffic.

DOE submitted to the U.S. Fish and Wildlife Service a biological assessment of the effects of construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain. The U.S. Fish and Wildlife Service has produced a Final Biological Opinion on the effects of construction, operation and monitoring, and closure of a geologic repository at Yucca Mountain (see Appendix O). The Final Biological Opinion establishes conditions for repository construction, operation and monitoring, and eventual closure as well as for the remaining site activities prior to repository construction (if the site was approved). The Final Biological Opinion does not evaluate effects that could occur to the desert tortoise from the construction of transportation infrastructure and transportation of materials.

In its Final Biological Opinion, the U.S. Fish and Wildlife Service lists five reasonable and prudent measures to minimize impacts to the desert tortoise, and then lists 18 terms and conditions with which DOE must comply to implement the five measures. The Final Biological Opinion states reporting requirements upon the location of an injured or dead desert tortoise and conservation recommendations to minimize or avoid adverse effects on listed species or critical habitat. If the repository was authorized, DOE would observe and implement all terms and conditions, reporting requirements, and conservation recommendations that the U.S. Fish and Wildlife Service has established in its Final Biological Opinion to protect the desert tortoise. DOE expects to observe and implement all terms and conditions, reporting requirements, and conservation recommendations in any future biological opinions regarding the effects of transportation or other project activities on the desert tortoise or other listed species.

As discussed in Chapter 4, the proposed repository location is at the extreme northern edge of the range of the desert tortoise, and the population of tortoises at that location is small in relation to other portions of its range. No part of the repository location has been declared critical habitat for the desert tortoise.

Desert Tortoise Measures under the Proposed Action

DOE adopts all impact reduction measures and all terms and conditions established by the U.S. Fish and Wildlife Service to protect the desert tortoise.

The following text summarizes the five reasonable and prudent measures established in the U.S. Fish and Wildlife Service's Final Biological Opinion (see Appendix O), and identifies the terms and conditions that the Biological Opinion has set forth to implement each reasonable and prudent measure:

1. Minimize take of desert tortoises due to project-related activities and operation of heavy equipment

- A qualified biologist would conduct clearance surveys for tortoises before vegetation removal or soil disturbance of more than 0.02 square kilometer (5 acres) or when records indicated that tortoises could occur in the area to be disturbed. Project activity would be moved if there was an adjacent area free of tortoises on which the activity could be conducted. If no suitable site was available, the biologist would determine the site having the smallest impact on tortoises and their habitat.

- The biologist would conduct 100 percent coverage clearance surveys the day before or the day of surface-disturbing activity, during the tortoise activity season, and within 7 days before surface-disturbing activity during hibernation. If tortoises or eggs were found, they would be moved pursuant to U.S. Fish and Wildlife Service guidelines. Burrows would be conspicuously flagged and avoided by at least 9 meters (30 feet).

- Unavoidable burrows would be inspected. If unoccupied, burrows would be collapsed to prevent tortoise entry. If tortoises or eggs were present, they would be excavated by hand and moved.

- If removed from a burrow, a tortoise would be placed in the shade of a shrub or an existing, similar, unoccupied burrow. A tortoise moved when in hibernation, estivation, or brumination (dormant states due to heat or cold) would be placed in an adequate unoccupied or constructed burrow.

- Project activities that could endanger a tortoise would cease if a tortoise was found on a project site and would not resume until after the tortoise moved or was moved out of danger by the biologist.

- A desert tortoise biologist or environmental monitor would be at the site during all phases of construction to ensure compliance with the Biological Opinion and to protect tortoises from harm. The environmental monitor would be responsible for: (1) enforcing the litter-control program; (2) ensuring that tortoise-proof fences were maintained; (3) ensuring that tortoise habitat disturbance was restricted to authorized areas; (4) ensuring storage of all equipment and materials within construction zones or previously disturbed areas; (5) ensuring that all vehicles used existing graded or paved roads or stayed within construction zones; (6) ensuring inspection of open trenches and other excavations; (7) ensuring that speed limits were observed; and (8) ensuring compliance with all terms and conditions of the Biological Opinion. Environmental monitors would not be authorized to handle tortoises.

- Vehicles would not be driven off existing roads in nonemergency situations unless authorized by DOE. Vehicle paths would be cleared of tortoises pursuant to terms of the Biological Opinion.

- Vehicles would be driven at speeds within posted limits on existing roads, and would not exceed 40 kilometers (25 miles) per hour on unposted roads.

- DOE would continue to present a tortoise education program to all employees on the project site and would address specific issues identified in the Biological Opinion. The education program would include definition of “take” and specification, actions that must be avoided, procedures for handling tortoises found on roads, and identification of personnel authorized to handle or otherwise capture and relocate tortoises.

- Marking or telemetry of tortoises would not be allowed.

2. Minimize entrapment of tortoises in open trenches.

    - During tortoise active season, all open trenches with slopes steeper than 0.3 meter (1 foot) rise per 0.9 meter (3 feet) of length would be fenced off, covered, or constructed with escape ramps if they were not immediately backfilled.

    - Open trenches would be inspected for entrapped animals immediately prior to backfilling.

    - If a tortoise was discovered in a trench, all activities associated with the trench would cease until a qualified biologist had removed the tortoise.

3. Minimize predation on tortoises by ravens drawn to the project area.

    - DOE would implement a litter control program that would include the use of covered, raven-proof trash receptacles; disposal of edible trash in trash receptacles after each workday; and disposal of trash in a sanitary landfill. Materials placed in a landfill would be covered often enough to prevent ravens and other predators from feeding in the area.

4. Minimize destruction of tortoise habitat due to project activities

    - DOE would revegetate areas no longer required by the project in accordance with existing procedures and pursuant to site-specific rehabilitation plans prepared in accordance with the Biological Opinion.

5. Ensure compliance with reasonable and prudent measures, terms and conditions, reporting requirements, and reinitiation requirements in the Biological Opinion.

    - DOE personnel would have to acquire appropriate State permits from the Nevada Division of Wildlife prior to handling a desert tortoise, carcass, or egg.

    - DOE would designate a field representative (who could also serve as the environmental monitor), who would be responsible for overseeing compliance with protective stipulations and for coordinating compliance with the terms and conditions of the Biological Opinion, and who would have authority to halt construction equipment activities that could be in violation of the protective stipulations.

    - DOE would keep an up-to-date log of all actions related to the consultation, including acreage affected, habitat rehabilitation actions completed, number of desert tortoises taken and by what means (injured, killed, captured and displaced, or found in trenches or pits). The information would be provided to the U.S. Fish and Wildlife Service Las Vegas Office in the form of an annual report on February 28 of each year during which activities addressed by the Biological Opinion occurred.

9.2.4.2 General Biological Resources and Soils

Impacts to biological resources at the Yucca Mountain site could include habitat fragmentation, loss of individual members of different species, and encroachment of noxious weeds.

Potential soil impacts or concerns related to the proposed repository can be categorized as (1) increased soil erosion rates, (2) slow recovery rate of disturbed soils in the Yucca Mountain environment, and (3) introduction of contaminants. Erosion could result in the loss of the thin topsoil from the disturbed areas, which could affect long-term recovery, be a threat to structures in the region, and result in increased depositions downhill.

General Biological Resources and Soils Measures Under the Proposed Action

- Use the measures described in Section 9.2.2 to control erosion, dust, and particulate matter and therefore to lessen the consequences for biological resources and soils from repository construction, operation and monitoring, and closure.

- Use dust suppression measures such as application of water or environmentally sensitive methods to minimize wind and other erosion and aid recovery on disturbed areas.

- Conduct preconstruction surveys in floodplains to ensure that work would not affect important biological resources and to determine the reclamation potential of sites.

- Consider measures to relocate or avoid sensitive species in floodplains.

- If construction could threaten important biological resources in floodplains, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation.

General Biological Resources and Soils Measures Under Consideration

- Align and locate facilities, roadways, cleared areas, laydown areas, and similar construction activities to minimize fragmentation of habitat potentially affected by the proposed project.

- Mitigate potential soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as stormwater runoff control through the use of holding ponds, baffles, and other devices and the compacting of disturbed ground, relocated soil, or excavated material in places outside desert tortoise habitat.

- Mitigate the introduction of contaminants to soils, using methods similar to those described for surface-water impacts (see Section 9.2.3.1).

- To aid recovery, strip and stockpile topsoil from disturbed areas (excavated rock pile, etc.). When the disturbed areas are no longer needed, spread the topsoil over the areas and reseed the soil to improve the success of vegetation reestablishment and prevent encroachment of invasive species.

- Provide escape ramps from ponds and basins.

9.2.5 CULTURAL RESOURCES

Land clearing, excavation, and construction activities have the potential to disturb or cause the relocation of cultural artifacts. The operation of industrial facilities can degrade the value of traditional sites or uses. In addition, human activity in project areas causes concern that members of the workforce could affect cultural resource sites, especially those at buried locations or with artifacts.

Actions that DOE would take to mitigate adverse impacts to cultural resources at Yucca Mountain include those required by law or regulation and those that DOE determined the project would include to reduce such impacts. In some cases, precise mitigation measures cannot be identified due to the limited nature of the data (for example, construction activities could reveal previously unidentified sites). To address these cases, programmatic mitigation measures that comply with historic preservation laws and regulations are in place to ensure that DOE would implement appropriate measures following the identification and evaluation of important cultural resources.

The *Programmatic Agreement Between the United States Department of Energy and the Advisory Council on Historic Preservation for the Nuclear Waste Deep Geologic Repository Program, Yucca Mountain, Nevada* (DIRS 104558-DOE 1988, all) contains the requirements and general procedures for the mitigation of adverse effects at important archaeological and historic sites in the Yucca Mountain region during site characterization. DOE would work to review and update that agreement to establish requirements and procedures for mitigation of any adverse effects at important archaeological and historic sites during construction, operation and monitoring, and closure of the proposed repository in the event the repository was authorized.

The *Research Design and Data Recovery Plan for the Yucca Mountain Project* (DIRS 103196-DOE 1990, all) outlines more detailed approaches and procedures for implementing the mitigation of impacts to archaeological sites. Along with other topics, that document provides specific guidelines for determining the rationale, methods, analytical requirements, and logistics for archaeological mitigation measures at Yucca Mountain. In addition, the Department would consult with affected Native American tribes and organizations to ensure that repository activities avoided or minimized adverse impacts to resources or places that are important to American Indians.

Cultural Resources Measures Under the Proposed Action

- Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. The training could include descriptions of the importance of different cultural resource types, procedures to follow if resources were encountered in the field, and employment-related and legal penalties for not following the requirements.

- Continue to use the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with Native American tribes and concentrate on the continued protection of important cultural resources. A considerable part of this effort could continue to be directed at protecting these resources and mitigating adverse effects to the fullest extent possible. Historically, as part of this program, members of Native American tribes have made recommendations to DOE about potential adverse effects, mitigation procedures that involve required consultation with tribal governments, and direct involvement of Native Americans in proposed project activities that could affect cultural resources or values (DIRS 102043-AIWS 1998, pp. 1-1, 2-3, and B-1 *et seq.*). Examples of suggested mitigations include incorporating the assistance of Native American people, continued protection of archaeological sites, funding Native American studies on impacts to natural resources and impacts from transportation (DIRS 102043-AIWS 1998, pp. 4-8 to 4-12).

- Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the research potential of sites.

- If construction could threaten important archaeological resources, and modification or relocation of roads or rail lines would not be reasonable, develop additional mitigation measures.

9.2.6 OCCUPATIONAL HEALTH AND PUBLIC SAFETY

There would be a potential for repository workers to be exposed to radiation during the operation and monitoring and closure phases of repository activities or to be injured or killed as a result of hazards present in the industrial workplace (Chapter 4, Sections 4.1.7 and 4.1.8; Chapter 8, Section 8.2.7).

Erionite and cristobalite are hazardous materials that occur naturally in the Yucca Mountain subsurface. Erionite occurs in strata at varying depths below the planned level of the repository. DOE is mapping these strata as part of a general approach that emphasizes avoidance of erionite. If erionite was encountered during drilling, DOE would shut down the affected portion of its operation until it could put proper controls in place.

Cristobalite, which occurs generally in the subsurface rock structure, could be released during excavation operations or in fugitive dust from the excavated rock pile. There would be a potential for cristobalite to be an inhalation hazard to workers. Implementing specific health and safety plans to prevent worker exposure would minimize risks. Chapter 4, Section 4.1.7, discusses erionite and cristobalite.

After closure, there would be potential for human intrusion that could result in release of radioactive materials.

Occupational and Public Health and Safety Measures Under the Proposed Action

- Avoid erionite-bearing strata where practicable during repository construction and drift development.
- If drilling encountered erionite, close operations in potentially affected areas until proper controls were in place.
- Use high-efficiency particulate air filters or similar controls if drilling occurred in an area where there is potential for encountering erionite.
- Design repository construction procedures to reduce the risk of worker inhalation of cristobalite or erionite.
- Specify features of ventilation systems and other underground equipment to ensure the elimination of opportunities for occupational exposure to health and safety hazards.
- Use ventilation, planned transfer of cristobalite from work areas, and scrubbing of in-place dust to minimize exposure. Use monitoring devices and respirators as appropriate.
- Use ventilation to keep radon levels low in subsurface areas. Use higher ventilation rates and shorter air travel paths to reduce worker exposure to radon.
- Unload, handle, and package spent nuclear fuel and high-level radioactive waste remotely in hot cells or under water.
- Provide appropriate shielding during operations and during shipping and handling of packages when personnel would be present and could be exposed.
- Minimize to the extent practicable the amount of time workers would spend in the subsurface environment.
- Design task procedures to reduce the potential for accidents.
- Implement health and safety procedures and administrative controls to minimize risks to construction and operations workers.
- Design task procedures to reduce the potential for accidents that could lead to radioactivity releases in the workplace environment.

9.2.7 AESTHETICS

Construction, operation and monitoring, and closure of the proposed repository would require the lighting of certain areas of the repository at night. While the repository site is remote, and there are existing sources of nighttime light in the region, nighttime darkness is a valued component of the solitude experience sought by many individuals. Nighttime darkness enhances astronomy and stargazing activities and is one of the important scenic resources of Death Valley National Park.

Aesthetics Measures Under the Proposed Action

- Use exterior lighting only where needed to accomplish facility tasks.

- Limit the height of exterior lighting units, focusing more light on the ground surface and reducing the effects of night lighting on surrounding areas. This limitation would enable the use of reduced wattage output lamps, but could require the use of additional lighting units to obtain the same amount of ground coverage.

- Use shielded or directional lighting to limit the effects of the lighting to areas where it is needed.

Aesthetics Measures Under Consideration

- Orient ventilation system stacks and support structures and use re-contouring and natural vegetation to reduce facility visibility.

9.2.8 UTILITIES, ENERGY, AND MATERIALS

A monitored repository at Yucca Mountain would require a range of utility services, energy to power a variety of activities, and a number of diverse materials. DOE intends to promote efficiency in the use of utilities, energy, and materials.

Utility, Energy, and Materials Measures Under the Proposed Action

- Implement procedures and equipment that would minimize the use of utility services, energy, and materials.

9.2.9 MANAGEMENT OF REPOSITORY-GENERATED WASTE AND HAZARDOUS MATERIALS

As part of the repository design, DOE would institute a waste minimization program similar to the waste minimization and pollution prevention awareness plan successfully implemented during site characterization activities to minimize quantities of generated waste and to prevent pollution (DIRS 103203-YMP 1997, all). In addition, DOE would consider innovations to augment the existing program. The Department could keep the size of the Restricted (for radiological control) Area as small as possible, and it could implement programs to ensure that construction and operation activities used, as practicable, smaller quantities of products such as solvents and cleaners. The design of the proposed repository would incorporate pollution prevention measures and would provide cradle-to-grave waste management, as DOE provided during site characterization.

Waste and Hazardous Materials Measures Under the Proposed Action

- Recycle wastewater to reduce the amount of water needed for repository facilities and the amount of wastewater that could require disposal (DIRS 100248-CRWMS M&O 1997, p. 14).

- Use practical, state-of-the-art decontamination techniques such as pelletized solid carbon dioxide blasting that would reduce waste generation in comparison with other techniques (DIRS 100248-CRWMS M&O 1997, pp. 9-13 and 9-14).

- Institute preventive maintenance and inventory management programs to minimize waste from breakdowns and overstocking (DIRS 104508-CRWMS M&O 1999, p. 55).

- Whenever practicable, recycle nonradioactive materials such as paper, plastic, glass, nonferrous metals, steel, fluorescent bulbs, shipping containers, oils, and lubricants rather than dispose of them (DIRS 104508-CRWMS M&O 1999, pp. 62 and 70). Encourage the reuse of materials and the use of recycled materials.

- Avoid use of hazardous materials where feasible.

Waste and Hazardous Materials Measures Under Consideration

- When protective of the environment and cost effective, recycle dual-purpose canisters.

- Recycle solar panels if cost-effective and environmentally sound recycling options are available.

9.2.10 LONG-TERM REPOSITORY PERFORMANCE

DOE proposes a repository at Yucca Mountain to provide for permanent disposal of spent nuclear fuel and high-level radioactive waste. DOE's proposal includes a natural geologic setting that, with engineered repository and waste package barriers, would provide long-term isolation of spent nuclear fuel and high-level radioactive waste. In its design process, DOE is considering many features and approaches to contain and isolate the materials it proposes to place in the repository.

DOE's detailed study of the Yucca Mountain site and vicinity has resulted in the evaluation of three categories of potential measures: Barriers to limit the release and transport of radionuclides, measures to control heat and moisture in the confined environment of the repository, and measures to improve operational efficiency or safety. Each of these measures has the potential to complement the site's natural characteristics. These measures are conceptual in nature. The following sections summarize design features that could contribute to a reduction of the long-term potential for impacts from radionuclides isolated in a Yucca Mountain Repository. Long-term performance measures are discussed in more detail in Appendix E.

Long-Term Performance Measures Under the Proposed Action

DOE has designed an engineered barrier system that would complement the geologic and hydrologic properties of Yucca Mountain to isolate radionuclides in spent nuclear fuel and high-level radioactive waste from accessible portions of the environment. Design features that are part of the Proposed Action are presented below. The repository flexible design described in Chapter 2 of this EIS can be operated in a range of operating modes, from higher- to lower-temperature. Measures that are unique to only one operating mode are so noted.

- Use two-layer waste packages designed to remain intact for thousands of years (at a minimum), with layers that would fail only from different mechanisms and at different rates.

- Encapsulate spent nuclear fuel (normally in zirconium-alloy cladding) and immobilize high-level radioactive waste (normally in borosilicate glass or ceramic matrices) in the waste packages.

- Use nickel-chromium alloy (Alloy-22) emplacement pallets to hold waste packages off the floors of emplacement drifts.

- Use heat generated from the decay of radioactive material to heat the surrounding rock to drive water and gas away from the emplaced waste packages (higher-temperature operating mode).

- Use drip shields to provide a partial barrier to divert infiltrating water away from waste packages in an emplacement drift.

- Ground support options – Placing an engineered system into repository drifts to ensure drift stability before closure could both enhance safety during emplacement and potential retrieval and improve long-term repository performance by reducing or delaying damage to canisters from rockfall (damaged areas are locations for enhanced corrosion even if the canister is not breached by the rockfall).

- Increase the spacing between waste packages or drifts, or reduce the size of waste packages and maintain spacing to potentially reduce uncertainties regarding elevated temperature of the host rock and reduce waste package material corrosion rates (lower-temperature operating mode).

- Waste package spacing and drift spacing – Emplacing waste packages nearly end-to-end [that is, with a 0.1-meter (0.3-foot)-gap] with no consideration of individual waste package characteristics would provide a more intense and uniform heat source along the length of emplacement, requiring an increase in emplacement drift spacing and, potentially, continuous ventilation of emplacement drifts, but also would keep emplacement drifts hot and dry for a longer period, decrease the amount of water that could contact waste packages, and reduce the number of emplacement drifts needed for waste emplacement (higher-temperature operating mode).

- Use preemplacement aging and blending of spent nuclear fuel and high-level radioactive waste to provide thermal performance benefits. Aging would reduce the total thermal energy that the repository must accommodate, and blending would reduce the variability in the distribution of the thermal energy in the repository drifts. Potential benefits would be improved rock stability and retardation of waste package degradation (lower-temperature operating mode).

- Continuous preclosure ventilation – Continuous ventilation in the emplacement drifts before repository closure would reduce rock wall and air temperatures and remove moisture to reduce corrosion rates and increase the stability of the ground support system.

- Timing of repository closure – Extending the period before final closure, together with a maintenance program to accommodate an extended long-term repository service life and ground support components designed and maintained for a service life of up to 300 years, would allow for reduction of waste package heat output after closure, extended monitoring before closure, and an extended retrieval period for the waste (lower-temperature operating mode).

Long-Term Performance Measures Under Consideration

The design features listed below are being considered, though some are not currently under active consideration. These features are organized by their design purpose, either to limit release and transport of radionuclides, control heat and moisture in the repository environment, or support operational considerations.

Barriers to Limit Release and Transport of Radionuclides. The most direct method to provide the long-term isolation of contaminants is to use structures and techniques that have the potential to inhibit directly the release of contaminants from waste packages or to reduce the likelihood of the transport of released contaminants from the repository. DOE is considering a range of barrier measures that could enhance resistance to corrosion, delay or reduce water transport, retard radionuclide movement and release rates, and reduce the potential for damage to canisters. The Department will continue to evaluate the potential benefits and consequences of these measures together with their compatibility with overall repository system design.

- Ceramic coatings on the exterior of the waste package – Could increase waste package life and repository waste isolation performance by reducing corrosion of the waste package surface and delaying the release of radionuclides.

- Diffusive barrier under waste packages – Loose, dry, granular material placed in the space between each waste package and the bottom of the emplacement drift to form a restrictive barrier to seepage, potentially slowing fluid and radionuclide movement to the natural environment.

- Getter under waste package – Placing a fine-grained material [either phosphate rock (apatite) or iron oxide (hematite, geothite, etc.] with an affinity for sorption of radionuclides in the recess below waste packages prior to waste emplacement could improve long-term waste isolation through retardation of radionuclide movement from the repository drifts.

- Canistered assemblies and waste-specific disposal containers – Placing spent fuel assemblies in canisters at the Waste Handling Building before inserting them into waste packages could provide an additional barrier and further limit mobilization of radionuclides if the waste package was breached.

- Additives and fillers – Placing materials (for example, oxides of iron and aluminum) into waste packages (in addition to those normally required for the basket material) to fill the basket and waste form void spaces could improve both the long-term repository performance (by retarding of release of radionuclides to the groundwater) and the long-term *criticality control*.

Measures to Control Heat and Moisture in the Repository Environment. Long-term influence over heat and moisture in the repository environment could increase the ability of the waste packages to isolate waste. DOE has evaluated measures that have the potential to control temperature and humidity levels in the repository to reduce corrosion rates, increase structural and support system stability, and increase the capability to retain released radionuclides in the repository. The Department will continue to examine the potential for enhancements in repository performance offered by these measures, other consequences of implementing them, and their compatibility with overall repository system design. DOE is considering the items listed below:

- Tailored waste package spatial distribution – Tailoring spatial distribution of the waste packages within the repository block according to waste package heat production, or the tendency of radionuclides in different packages to travel, resulting in a more uniform temperature across the repository. This would improve the performance of waste packages by delaying and reducing contact of water and/or increasing sorption of released radionuclides by zeolites in the unsaturated zone, thereby potentially improving repository waste isolation performance.

- Continuous postclosure ventilation design – Continuous ventilation of the emplacement drifts during the postclosure period could increase removal of moisture from air around the waste packages for a period of time (though moisture would eventually reestablish itself), and it could improve performance by retarding waste package corrosion.

- Drift diameter – A smaller diameter drift would be more stable (less rockfall potential), could reduce seepage into the drifts, and could reduce the need for ground support systems, while a larger diameter drift would allow for other modes of emplacement, such as horizontal or vertical borehole emplacement.

- *Near-field* rock treatment during construction – Filling cracks in a portion of the rock above each emplacement drift with grout to reduce or retard water seepage into the drifts after closure of the repository.

- Surface modification (alluvium) – Covering the surface of Yucca Mountain above the repository footprint with alluvium (soil) could decrease the net infiltration of precipitation water into the repository.

- Surface modification (drainage) – Removing the thin alluvium layer over the footprint of the repository would promote rapid runoff of surface water, potentially reducing infiltration from the top and improving long-term isolation of the waste.

Repository Designs to Support Operational Considerations. Including elements in the design that would enhance the repository's operational capabilities could improve access to waste packages after their emplacement, increase access for conducting performance confirmation, inspection, and maintenance activities, ease any effort to augment the repository system with later-developed materials or processes, and facilitate retrieval of waste packages if retrieval became necessary. DOE is considering measures that could provide additional shielding for personnel, increase usable space in drifts, increase opportunities for monitoring, and reduce the potential for moisture to contact waste packages. The Department will continue to assess the potential for design modifications to assist operational activities within the context of overall repository system design. DOE is considering the following potential design modification measures:

- Rod consolidation – Rod consolidation would involve bringing fuel rods into close contact with one another, allowing the capacity of waste packages to be increased and/or the size of waste packages to be reduced, potentially reducing the size or number of waste packages and, if consolidation were accomplished at the reactor sites, possibly reducing waste transportation shipments.

- Waste package self shielding – Adding a shielding material on the outside of waste packages would reduce the radiation in the drifts to levels such that personnel access would be possible.

- Repository horizon – A two-level repository would increase repository capacity without moving out of the characterized area. It would increase thermal load to reduce the amount of water that could come in contact with waste packages; add flexibility in emplacing waste packages on the lower level, which could be shielded from moisture infiltration by the upper level; and potentially facilitate retrieval due to the ability to operate two independent retrieval operations at the same time.

9.3 Transportation

This section discusses mitigation measures DOE is required to implement, has determined to implement, or has identified for consideration, to reduce potential impacts from the national transportation of spent nuclear fuel and high-level radioactive waste. These measures address impacts from the possible construction of a branch rail line or an intermodal transfer station in Nevada; construction of other transportation routes; upgrading of existing Nevada highways to accommodate heavy-haul vehicles; transportation of spent nuclear fuel and high-level radioactive waste from existing storage sites to the proposed repository; and fabrication of casks and canisters.

9.3.1 LAND USE

Mitigation measures could address three types of potential land-use impacts resulting from the construction and operation of a rail line or an intermodal transfer station: (1) impacts to publicly used lands such as grazing allotments, (2) direct and indirect land loss, and (3) displacement of capital improvements. Mitigation would not necessarily be associated with the potential selection of a route for heavy-haul trucks, which would follow existing rights-of-way and would require little additional land disturbance.

Land Use Measures Under the Proposed Action

- Ensure that construction activities were consistent with best management practices, by:

  – Ensuring that the location selection and final route alignment for a branch rail line or location selection for an intermodal transfer station, in consultation with parties controlling the surrounding lands, consider (1) the minimum impacts to private lands, capital improvements, floodplains or wetlands, areas containing cultural resources, or other environmentally sensitive areas, and (2) indirect loss of land or loss of use of land (the division of property or limitation of access) such as the use of grazing allotments.

  – Minimizing the size and number of easements.

  – During the rail construction phase, locating construction camps and staging areas along the rail line in consultation with parties controlling the surrounding lands.

  – Reclaiming disturbed areas outside the permanent right-of-way as soon as practicable after completion of construction.

Land Use Measures Under Consideration

- For grazed lands (lands grazed on by cattle), provide access across routes via underpasses, revegetate disturbed land, and aid in water provision (if access to water sources by herds is impeded).

- Coordinate DOE transportation schedules with U.S. Air Force training schedules to ensure that transportation of spent nuclear fuel and high-level radioactive waste through Air Force-controlled lands to a Yucca Mountain Repository would not result in safety-related restrictions being imposed on Air Force training activities.

- Implement additional rail realignments where feasible to avoid safety-imposed restrictions on U.S. Air Force use of lands the Air Force controls and uses for training purposes.

- If DOE selected the Bonnie Claire Alternate to the Caliente or Carlin rail corridor as part of its transportation route to Yucca Mountain, evaluate the potential for realignment of this alternate to reduce or eliminate the taking of land from the Timbisha Shoshone Trust Lands.

- Initiate no construction that would cross any presently designated wilderness study area unless that study area had been released from interim status by the State Director of the Bureau of Land Management as nonsuitable for wilderness or Congress has acted to remove the Wilderness Study Area designation.

9.3.2 AIR QUALITY

If DOE selected the Valley Modified rail corridor, mitigation measures could be needed to reduce fugitive dust emissions from rail line construction and carbon monoxide emissions from operations in the Las Vegas Valley nonattainment area. As described in Chapter 6, Section 6.3.2.2.5, fugitive dust emissions during the construction phase could be above the General Conformity Rule minimal levels for particulates. Vehicles used to transport workers and trains used to transport materials would generate criteria pollutants. States could place requirements for control of emissions of volatile organic compounds and nitrous oxide on facilities that manufacture containers and casks.

Air Quality Measures Under Consideration

- Employ two construction crews at half pace from opposite ends if the Valley Modified rail line was selected. Because only approximately 50 percent of the corridor length is in the Las Vegas Valley air basin, emission rates would be reduced to levels at or below General Conformity thresholds.
- Use buses to transport workers, reducing nitrogen oxide and hydrocarbon emissions.
- Reduce fugitive dust emissions using standard dust control measures routinely applied during construction projects including, for example, routine watering of unpaved surfaces; wet suppression for material storage, handling, and transfer operations; and wind fences to control windblown dust. The efficiency of these controls tends to vary depending on site characteristics, but it ranges from a 60- to 80-percent reduction in fugitive dust emissions (DIRS 103676-Cowherd, Muleski, and Kinsey 1988, p. 5-22).
- Reduce maximum fugitive dust concentrations with working controls such as scheduling construction operations to minimize concurrent generation by activities that were near each other (for example, conducting adjacent clearing and grading activities at different times).

9.3.3 HYDROLOGY

This section describes potential mitigation actions for both surface water and groundwater.

9.3.3.1 Surface Water

Three categories of potential impacts to surface water from the construction and operation of a Nevada transportation route are (1) the introduction of contaminants, (2) the alteration of drainage patterns or runoff rates, and (3) flood hazards. The spread of contamination by surface water could result in adverse impacts to plants and animals or to human health in the immediate area. It could also result in the recharge of contaminated water to groundwater. DOE's intent is to respond rapidly to such spills with appropriate cleanup actions.

Surface-Water Measures Under the Proposed Action

- Minimize disturbance of surface areas and vegetation, thereby minimizing changes in surface-water flow and soil porosity that would change infiltration and runoff rates.
- Mitigate flood hazards by designing facilities to withstand or accommodate a 100-year flood.
- Minimize the potential for contamination spread or other physical impacts to surface water by avoiding spills in unconfined areas and areas subject to flash floods, where practicable, and by locating the alignment of a branch rail line or heavy-haul road to avoid floodplains and surface waters, including wetlands, springs, and riparian areas, when possible, and to minimize any potential impacts to these features.
- Maintain natural contours to the maximum extent feasible, stabilize slopes, and avoid unnecessary offroad vehicle travel to minimize erosion.
- Minimize physical changes to drainage channels by building bridges or culverts where roadways would intersect areas of intermittent water flow. Use erosion control features such as proper placement of pipe, revegetation, and use of erosion control at these intersections where practicable to enhance the effectiveness of the bridges or culverts.

- Use physical controls such as secondary containment for fuel storage tanks to reduce the potential for releases to mingle with stormwater runoff.

- In and near floodplains, follow reclamation guidelines (DIRS 102188-YMP 1995, all) for site clearance, topsoil salvage, erosion and runoff control, recontouring, revegetation, siting of roads, construction practices, and site maintenance.

- Implement best management practices including training employees in the handling, storage, distribution, and use of hazardous materials to provide practical prevention and control of potential contamination sources.

- Conduct fueling operations and store hazardous materials and other chemicals in bermed areas away from floodplains to decrease the probability of an inadvertent spill reaching the floodplains.

- Provide rapid response cleanup and remediation capability, techniques, procedures, and training for potential spills.

Surface-Water Measures Under Consideration

- Designate bermed or contained sites outside areas subject to flash flooding for fueling and chemical handling to minimize the potential for contamination spreading if spills occurred.

9.3.3.2 Groundwater

Potential transportation-related impacts to groundwater would be most likely to occur from construction activities associated with a potential Nevada transportation route and could include introduction of contaminants and alteration of infiltration and runoff rates that could change the rate of recharge to the aquifer. Design and operational actions to reduce impacts would be identical to those described above for surface-water impacts.

Groundwater Measures Under the Proposed Action

- Implement best management practices, such as training employees in the handling, storage, distribution, and use of hazardous materials, to provide practical prevention and control of potential contamination sources.

- Minimize surface disturbance, thereby minimizing changes in surface-water flow and soil porosity that could change infiltration and runoff rates.

Groundwater Measures Under Consideration

- Place construction wells only in undesignated basins. (A Designated Groundwater Basin is one in which the quantity of appropriated water approaches or exceeds the perennial yield as *determined* by the Nevada State Engineer.)

- Employ water-use minimization and recycling techniques to reduce water consumption.

9.3.4 BIOLOGICAL RESOURCES AND SOILS

9.3.4.1 Desert Tortoise

The desert tortoise is a Federally protected species that resides at or along the candidate rail corridors, intermodal transfer station locations, and routes for legal-weight and heavy-haul trucks in Nevada (see Chapter 6, Sections 6.3.1, 6.3.2.1, and 6.3.3.1). Activities that could cause impacts to desert tortoises include site clearing, vehicle traffic, pond management, and taking of habitat.

DOE has been conducting site characterization activities in accordance with Fish and Wildlife Service biological opinions on the potential for impacts to desert tortoises (DIRS 104618-Buchanan 1997, pages 1 and 2). During these activities, five desert tortoises are known to have been killed by site characterization activities, all by vehicle traffic. A recent report (DIRS 103194-CRWMS M&O 1998, page 9) indicates that 27 of 28 individual tortoise relocations were successful and that two nest relocations were also successful. The one unsuccessful relocation involved a tortoise that returned to the area of disturbance and became one of the five killed by traffic.

If the proposed project proceeded, the U.S. Fish and Wildlife Service would establish measures, terms, and conditions for transportation activities that DOE would have to observe to protect the desert tortoise. DOE would implement terms and conditions established in any future biological opinions regarding the effects of repository-related transportation activities on the desert tortoise. As discussed in Chapter 6, areas that would be affected by transportation activities are at the extreme northern edge of the range of the desert tortoise, and the population of tortoises in these areas is low in relation to other portions of its range. No part of any of the candidate transportation routes has been declared critical habitat for the desert tortoise.

The final biological opinion on site characterization (DIRS 104618-Buchanan 1997, pp. 19 to 25) identified the following actions as requirements that DOE would need to implement to minimize impacts on desert tortoises. The U.S. Fish and Wildlife Service could establish similar conditions as prerequisites for transportation activities associated with the proposed project.

- Alignment and final siting of facilities, construction roadways, cleared areas, laydown areas, and similar elements of construction activity could avoid sensitive areas, lessen the likelihood of entrapment of tortoises, and minimize the fragmentation of known desert tortoise habitat.

- Measures to control erosion, dust, and particulate matter would lessen consequences of repository construction, operation and monitoring, and closure for desert tortoises. Similarly, approaches to minimize soil compaction and crushing of vegetation would lessen consequences for desert tortoises.

- Clearance surveys for desert tortoises before vegetation removal or soil disturbances of more than about 2 hectares (5 acres).

- Removal of tortoises or tortoise eggs found in areas to be disturbed, and tortoises in immediate danger along roads or near ongoing activities to safe nearby locations, with project activity ceasing until removal occurred.

- Prohibitions against driving vehicles off existing roads in nonemergency situations unless authorized. All workers at Yucca Mountain would participate in a required tortoise education program.

- A litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles following the end of each workday, and disposal of trash in a designated sanitary landfill.

- Revegetation of project areas no longer required.

- Construction and maintenance of tortoise-proof fencing to lessen the potential for endangerment to desert tortoises from project-related activities.

- Placement of escape ramps in trenches and inspection of trenches before filling.

Desert Tortoise Measures Under the Proposed Action

If a consultation process resulted from a determination that construction or operation of a transportation corridor associated with the proposed repository could affect threatened or endangered species or their habitat, DOE will adopt all reasonable and prudent measures to protect the desert tortoise or other species that could be stated in future biological opinions on transportation corridors.

The following text discusses potential transportation-related measures DOE has identified for the protection of the desert tortoise based on determinations the U.S. Fish and Wildlife Service made for site characterization.

- Align and locate facilities, roadways, and cleared areas and place appropriate signs to lessen the likelihood of trapping tortoises and to minimize habitat fragmentation.
- Minimize soil compaction and vegetation crushing.
- Move desert tortoises or desert tortoise eggs from areas to be disturbed, from roadways, and from proximity to ongoing activities to safe nearby locations; stop project activity until completion of these actions.
- Require authorization for nonemergency offroad vehicle travel.
- Ensure that all workers on the Yucca Mountain Project participate in a tortoise education program.
- Establish a litter-control program that would include the use of covered, raven-proof trash receptacles, disposal of edible trash in trash receptacles at the end of each workday, and disposal of trash in a designated sanitary landfill located away from desert tortoise habitat in order to avoid attracting potential predators.
- Revegetate project areas no longer required for the Proposed Action.
- Post road signs to remind drivers of the presence of desert tortoises and other animals, and enforce speed limits.
- Construct and maintain tortoise-proof fencing around actively used construction and operation sites to lessen the potential for danger from project-related activities.
- Provide escape ramps from trenches; inspect trenches before filling them.

9.3.4.2 General Biological Resources and Soils

Certain herds of migratory animals could be substantially affected if they were prevented from moving between ranges used at different times of the year. Some of the transportation routes under consideration cross game management areas and wild horse and wild burro management areas. Some routes cross areas traversed by herds of antelope, mule deer, elk, and mountain sheep. Fencing would not be likely to affect the movement of mule deer and elk. Fencing could impede the movements of antelope, mountain sheep, wild horses, and wild burros, effectively dividing management areas for these species.

General Biological Resources and Soils Measures Under the Proposed Action

- Use the measures described in Section 9.2.2 to control erosion, dust, and particulate matter and therefore to lessen the consequences for biological resources and soils from transportation activities.

- Use dust suppression measures on disturbed areas to minimize erosion and aid recovery by reducing wind erosion and supporting compaction.
- Conduct preconstruction surveys in floodplains to ensure that work would not affect important biological resources and to determine the reclamation potential of sites.
- Consider measures to relocate sensitive species in floodplains.
- If construction could threaten important biological resources in floodplains, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation.

General Biological Resources and Soils Measures Under Consideration

- Mitigate the introduction of contaminants to soils, using methods similar to those described for surface-water impacts (see Section 9.3.3.1).
- Conduct surveys of areas along the transportation corridor selected for construction to locate areas that are potential habitats for sensitive or State-protected species before the beginning of construction activities. Avoid springs, wetlands, waters of the United States, and riparian areas where practicable.
- Reduce habitat fragmentation and barriers to animal movement by considering the needs and movement patterns of mobile species (for example, wild horses) in the design and construction of rail lines, routes, and fencing. Seek input from wildlife agencies and organizations.
- If the construction and operation of a transportation route in Nevada could not avoid springs and wetlands, minimize the amount of disturbance (to the maximum extent possible) by carefully timing construction activities; minimizing corridor widths; locating laydown, excavated rock pile, and fueling areas away from sensitive areas where practicable; and conducting any wetlands replacement activities in accordance with plans approved by the U.S. Army Corps of Engineers.
- Align and locate facilities, roadways, cleared areas, laydown areas, and similar construction activities to minimize fragmentation of habitat potentially affected by the proposed project.
- Mitigate potential soil erosion by minimizing areas of surface disturbance and using engineering practices to stabilize disturbed areas. These practices could include such measures as stormwater runoff control through the use of holding ponds, baffles, and other devices and the compacting of disturbed ground, relocated soil, or excavated material in places outside desert tortoise habitat.
- To aid recovery, strip and stockpile topsoil from disturbed areas. When the disturbed areas were no longer needed, spread the topsoil over the areas and reseed the soil using local seed sources to improve the success of vegetation reestablishment and prevent encroachment of non-native invasive species.

9.3.5 CULTURAL RESOURCES

Land clearing, excavation, and construction activities have the potential to disturb or cause the relocation of cultural artifacts. The operation of industrial facilities can degrade the value of traditional sites or uses. In addition, human activity in project areas causes concern that members of the workforce could affect cultural resource sites, especially those at buried locations or with artifacts.

Actions that DOE would take to mitigate adverse impacts to cultural resources along transportation routes include those required by law or regulation and those built into the project to reduce such impacts. In some cases, DOE cannot identify precise mitigation measures due to the limited nature of the data (for example, construction activities could reveal previously unidentified sites). To address these cases, DOE has programmatic mitigation measures that comply with historic preservation laws and regulations in place to ensure that it would implement appropriate actions after the identification and evaluation of important cultural resources.

Cultural Resources Measures Under the Proposed Action

- Ensure that onsite employees complete cultural resource sensitivity and protection training to reduce the potential for intentional or accidental harm to sites or artifacts. The training could include descriptions of the importance of different cultural resource types, procedures to follow if resources were encountered in the field, and employment-related and legal penalties for not following the requirements.

- Continue to use the Yucca Mountain Project Native American Interaction Program, which has been in existence since 1985, to promote a government-to-government relationship with Native American tribes and concentrate on the continued protection of important cultural resources. A considerable part of this effort could continue to be directed at protecting these resources and mitigating adverse effects to the fullest extent possible. Historically, as part of this program, members of Native American tribes have made recommendations to DOE about potential adverse effects, mitigation procedures that involve required consultation with tribal governments, and direct involvement of Native Americans in proposed project activities that could affect cultural resources or values (DIRS 102043-AIWS 1998, p. 2-19). AIWS (DIRS 102043-1998, p. 4-1) suggested mitigations such as setting aside important cultural and ceremonial areas, and assisting in revegetation and reclamation activities.

- Conduct preconstruction surveys to ensure that work would not affect important archaeological resources and to determine the research potential of sites.

- If construction could threaten important archaeological resources, and modification or relocation of the roads and rail line would not be reasonable, develop additional mitigation measures.

9.3.6 OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY

Over time, traffic accidents involving vehicles associated with the proposed repository would occur. The analysis indicated that fatalities and injuries from traffic accidents (nonradiological events) probably would constitute the largest impact to public health associated with the project. (See the Occupational and Public Safety and Health sections in Chapters 4 and 6.)

During the transportation of spent nuclear fuel and high-level radioactive waste, drivers and escort personnel would be routinely exposed to radiation and would receive radiological doses from this exposure. Workers and members of the public could receive doses from exposures resulting from an accident that released radionuclides.

Apart from impact findings and mitigations discussed in the EIS, Section 180(c) of the NWPA allows DOE to provide technical assistance and funds to states for training local government and Native American tribal public safety officials through whose jurisdictions DOE could plan to transport spent nuclear fuel or high-level radioactive waste. The training would cover procedures for safe routine transportation and for emergency response situations.

Occupational and Public Health and Safety Measures Under the Proposed Action

- Design task procedures to reduce the potential for accidents that could lead to radioactivity releases in the workplace environment.

Occupational and Public Health and Safety Measures Under Consideration

- Establish contract requirements to minimize worker exposure to ionizing radiation.
- Promote alternative transportation such as buses for workers to reduce automobile accidents.
- Implement a radiation protection plan for drivers and escort personnel.
- Implement accident reduction measures such as the Commercial Vehicle Safety Alliance procedures.

9.3.7 NOISE AND VIBRATION

Noise and vibration impacts could occur along a transportation corridor, depending on the scenario. Native Americans have expressed concern about noise associated with the transportation corridors and the movement of spent nuclear fuel and high-level radioactive waste to the proposed repository (DIRS 102043-AIWS 1998, p. 2-16). Impacts could result from the construction and operation of the facilities associated with transportation. There is concern that transportation activities could disrupt ceremonies that address Native American concerns for ecological health and the solitude needed for healing or prayer. Other communities could be subject to adverse noise and vibration levels, depending on the selected route and the potential to reduce such consequences. DOE expects the potential for adverse impacts from noise and vibration to be low.

Noise and Vibration Control Measures Under Consideration

- Avoid areas with sensitive receptors.
- Avoid Native American ceremonial sites.
- Consider noise and vibration intensity, time and distance, and noise canceling or interference factors when planning construction activities and facilities.
- If the transportation corridor passes through areas close to sensitive human receptors (schools, institutions, etc.), plan for noise abatement walls to reduce noise levels at specific locations.
- If the transportation corridor passes through areas close to structures and facilities that are sensitive to vibration (historic structures), plan for vibration abatement measures such as control of speed at specific locations.
- Install equipment that meets decibel limitations (see Chapter 6).
- Schedule vehicle travel through communities during daylight hours.
- Ensure that the receipt and transfer of material from railcars to heavy-haul trucks at an intermodal transfer station occurred during daylight hours.
- Impose speed limits on train or truck operations to reduce the intensity of noise and vibration in areas where there are sensitive receptors.

9.3.8 AESTHETICS

Construction along transportation routes and at facilities such as intermodal transfer stations and overnight stopping areas could reduce the quality of views in key locations. The operation of intermodal transfer stations and overnight stopping areas would require the lighting of these areas at night.

Aesthetics Measures Under the Proposed Action

- Remove or shape construction spoil piles to reflect existing contours. Keep the height of spoil piles that could not be removed or contoured to a minimum.

- Reclaim borrow areas using native vegetation.
- Plant native seedlings and other vegetation to help screen or reduce texture and color contrasts from key observation locations.
- Conduct an active misting and spraying program during construction to minimize the effects of fugitive dust.
- Reduce effects from outdoor night lighting used for intermodal transfer stations and overnight stopping areas by using measures similar to those discussed for lighting equipment above in Section 9.2.7.

9.3.9 MANAGEMENT OF WASTE AND HAZARDOUS MATERIALS

The manufacture of casks and containers could produce liquid and solid waste streams that would require disposal.

Waste and Hazardous Materials Measures Under the Proposed Action

- Design construction to include use of materials, such as depleted uranium, that could otherwise require disposal as wastes.
- Recycle lubricating and cutting oils.
- Recycle solid waste components where practicable.
- Employ ion exchange and filtration or similar methods to treat water used for ultrasonic weld testing for reuse in the manufacturing process.

REFERENCES

Note: In an effort to ensure consistency among Yucca Mountain Project documents, DOE has altered the format of the references and some of the citations in the text in this Final EIS from those in the Draft EIS. The following list contains notes where applicable for references cited differently in the Draft EIS.

102043	AIWS 1998	AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.
104618	Buchanan 1997	Buchanan, C.C. 1997. "Final Biological Opinion for Reinitiation of Formal Consultation for Yucca Mountain Site Characterization Studies." Letter from C.C. Buchanan (Department of the Interior) to W. Dixon (DOE/YMSCO), July 23, 1997, File No. 1-5-96-F-307R. ACC: MOL.19980302.0368.
103676	Cowherd, Muleski, and Kinsey 1988	Cowherd, C.; Muleski, G.E.; and Kinsey, J.S. 1988. *Control of Open Fugitive Dust Sources, Final Report.* EPA-450/3-88-008. Research Triangle Park, North Carolina: U.S. Environmental Protection Agency. TIC: 243438.

100248	CRWMS M&O 1997	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1997. *Secondary Waste Treatment Analysis.* BCBD00000-01717-0200-00005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971208.0201. In the Draft EIS, this reference was cited as DOE 1997l in Chapter 12.
103194	CRWMS M&O 1998	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1998. *Efficacy of Relocating Desert Tortoises for the Yucca Mountain Site Characterization Project.* B00000000-01717-5705-00032 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981014.0309. In the Draft EIS, this reference was cited as DOE 1998h in Chapter 12.
104508	CRWMS M&O 1999	CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1999. *Repository Surface Design Engineering Files Report.* BCB000000-01717-5705-00009 REV 03. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990615.0238. In the Draft EIS, this reference was cited as TRW 1999a in Chapter 12.
104558	DOE 1988	DOE (U.S. Department of Energy) 1988. *Programmatic Agreement Between the United States Department of Energy and the Advisory Council on Historic Preservation for the Nuclear Waste Deep Geologic Repository Program Yucca Mountain, Nevada.* Washington, D.C.: U.S. Department of Energy. ACC: HQX.19890426.0057. In the Draft EIS, this reference was cited as DOE 1988b in Chapter 12.
103196	DOE 1990	DOE (U.S. Department of Energy) 1990. *Research Design and Data Recovery Plan for Yucca Mountain Project.* Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: NNA.19910107.0105.
110625	DOE 1999	DOE (U.S. Department of Energy) 1999. *A Roadmap for Developing Accelerator Transmutation of Waste (ATW) Technology.* DOE/RW-0519. Washington, D.C.: U.S. Department of Energy. TIC: 245890.
156711	DOE 2001	DOE (U.S. Department of Energy) 2001. *The Advanced Accelerator Applications Program Plan.* Washington, D.C.: U.S. Department of Energy, Office of Nuclear Energy, Science and Technology.
103403	National Research Council 1996	National Research Council 1996. *Nuclear Wastes, Technologies for Separations and Transmutation.* Washington, D.C.: National Academy Press. TIC: 226607.
102188	YMP 1995	YMP (Yucca Mountain Site Characterization Project) 1995. *Reclamation Implementation Plan.* YMP/91-14, Rev. 1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19970109.0256. In the Draft EIS, this reference was cited as DOE 1995g in Chapter 12.

103203	YMP 1997	YMP (Yucca Mountain Site Characterization Project) 1997. *Waste Minimization and Pollution Prevention Awareness Plan.* YMP/95-01, Rev. 1. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19980224.0441. In the Draft EIS, this reference was cited as DOE 1997h in Chapter 12.

12. REFERENCES

Chapter 12 of the Draft Environmental Impact Statement (EIS) listed all of the references cited in Chapters 1 through 11 of that document. For this Final EIS, the U.S. Department of Energy (DOE or the Department) has put a list of references at the end of each chapter that is specific to that chapter. DOE feels that this makes it easier for the reader to find the complete citations relevant to each chapter. Information regarding the availability of these references can be found in the DOE Reading Rooms (as listed in Appendix D) or on the internet at the Yucca Mountain Project website at *http://www.ymp.gov*.

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10. UNAVOIDABLE ADVERSE IMPACTS; SHORT-TERM USES AND LONG-TERM PRODUCTIVITY; AND IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES

This chapter discusses adverse impacts that would remain after the application of mitigation measures (see Chapter 9). It analyzes the relationship between short-term uses of the human environment and the maintenance and enhancement of long-term productivity, and it identifies irreversible or irretrievable commitments of resources. The chapter presents information drawn from the analysis of the Proposed Action. It summarizes and consolidates information from the impact and mitigation analyses in Chapters 4, 5, 6, and 9, and provides references to earlier chapters for readers who require more detailed information.

The chapter discusses only resource areas for which preceding analyses have identified some potential for unavoidable adverse impacts. Nevertheless, the discussions in Sections 10.1, 10.2, and 10.3 reflect an examination of all of the resource areas analyzed in this EIS.

The construction, operation and monitoring, and eventual closure of the proposed Yucca Mountain Repository and the associated transportation of spent nuclear fuel and high-level radioactive waste would have the potential to produce some environmental impacts that the U.S. Department of Energy (DOE) could not mitigate. Similarly, some aspects of the Proposed Action could affect the long-term productivity of the environment or would require the permanent use of some resources.

10.1 Unavoidable Adverse Impacts

This section summarizes potential impacts associated with the proposed repository and transportation actions that would be unavoidable and adverse and that would remain after DOE implemented mitigation measures, which are discussed in Chapter 9. Some aspects and activities discussed in Section 10.1 are analyzed from different perspectives in Sections 10.2 and 10.3.

10.1.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes unavoidable adverse impacts associated with the construction, operation and monitoring, closure, and long-term performance of the proposed repository.

10.1.1.1 Land Use

To develop the proposed Yucca Mountain Repository, DOE would need to obtain permanent control of land surrounding the Yucca Mountain site. DOE could obtain permanent control over the land only if Congress completed a land withdrawal action. A Congressional withdrawal would include lands already withdrawn for the Nevada Test Site and Nellis Air Force Range as well as lands under the control of the Bureau of Land Management and not currently withdrawn.

In general, the permanent withdrawal of land for the repository would prevent human use of the withdrawn lands for other purposes. Nevada Test Site activities would continue on a noninterference basis unless the Congressional land withdrawal specifically precluded them. DOE would remove mining and mineral claims from public use as they expired. Because the Yucca Mountain site has a low present resource value, is remote, and is partly withdrawn, the resultant impact would be small.

The disposal of spent nuclear fuel and high-level radioactive waste would permanently affect the availability of the subsurface area of the Yucca Mountain site and surface portions posted as off limits.

The Chapter 4 land-use discussion includes the availability of the land and the consequences of withdrawal.

10.1.1.2 Air Quality

Construction, operation and monitoring, and closure of a repository at Yucca Mountain would produce small impacts to regional air quality. Radiological impacts could occur from the release of radionuclides. The principal radionuclides released from the subsurface would be naturally occurring radon-222 and its decay products in ventilation exhaust air. There are no applicable regulatory limits for radon releases from Yucca Mountain facilities. Other impacts would come from criteria pollutants and materials such as cristobalite and erionite. Exposures of maximally exposed individuals to radionuclides and criteria pollutants would be a small fraction of applicable regulatory limits. If offsite manufacturing occurred in nonattainment areas, the manufacturing processes could detract from the ability of local governments to meet air quality goals.

10.1.1.3 Hydrology

Construction activities would temporarily restrict and minimally alter natural surface-water drainage channels. Facilities and roadways would be designed to withstand at least a 100-year flood. Therefore, after construction was complete, only flow from infrequent more-intense floods would affect those facilities and roadways. Ground-disturbing activities and the surface facilities that DOE would build would alter surface-water infiltration and runoff rates in localized areas. Given the relatively small size of the affected land in comparison to the total drainage area, drainage channels and washes would experience little difference in impacts as a result of the disturbances. DOE estimates that overall consequences from the construction of roadways and facilities would be minimal.

The proposed repository construction and operation would unavoidably involve crossing washes designated as floodplains in the vicinity of Yucca Mountain, but effects on these washes would be small.

There would be withdrawals of groundwater during construction, operations and monitoring, and closure, but they would not exceed estimates of perennial yield. Chapter 4, Section 4.1.3, provides details on the effects of repository construction, operation and monitoring, and closure on hydrology.

Analysts estimate that the placement of drip shields would prevent dripping water from reaching the waste packages for more than 10,000 years (DIRS 154659-BSC 2001, Figure 4.2.5.1, p. 4F-39. Therefore, with the potential exception of a very small number of waste packages (0 to 3) that could fail due to manufacturing defects, there would be no breaches of waste packages before 10,000 years.

If water entered a waste package, it would have to penetrate the metal cladding of the spent nuclear fuel to reach the waste. For approximately 99 percent of the commercial spent nuclear fuel, the cladding is highly corrosion-resistant metal designed to withstand the extreme temperature and radiation environment in the core of an operating nuclear reactor. Current models indicate that it would take thousands of years to corrode cladding sufficiently to allow water to reach the waste and begin to dissolve the radionuclides.

During the thousands of years required for water to reach the waste, the radioactivity of most radionuclides would decay to virtually zero. Remaining radionuclides would have to dissolve in the water to pass from a waste package. Few of the remaining radionuclides could dissolve at a meaningful rate. Thus, only long-lived water-soluble radionuclides could get out of a waste package. Long-lived water-soluble radionuclides that migrated from the waste packages would then have to move down through about 300 meters (about 1,000 feet) of rock to the groundwater and then travel about 18 kilometers (11 miles) to reach a point where they could be taken up in a well and consumed or used to irrigate crops (see Chapter 5, Sections 5.3 and 5.4).

As the long-lived water-soluble radionuclides began to move down through the rock, some would stick (or adsorb) to the minerals in the rock and be delayed in reaching the water table. After reaching the water table, radionuclides would disperse to some extent in the larger volume of groundwater beneath Yucca Mountain, and the concentrations would be diluted. Eventually, groundwater with varying concentrations of different radionuclides could reach locations in the hydrologic (groundwater) region of influence where the water could be consumed.

Of the approximately 200 different radioactive isotopes present in spent nuclear fuel and high-level radioactive waste, 26 are present in sufficient quantities and are sufficiently long-lived, soluble, mobile, and hazardous to contribute meaningfully to calculated radiation exposures.

10.1.1.4 Biological Resources and Soils

Unavoidable adverse impacts to biological resources would include the loss of small pieces of habitat totaling less than 6 square kilometers (2.5 square miles or 1,500 acres). The pieces that would be disturbed are habitat for terrestrial plant and animal species that are widespread throughout the region and typical of the Mojave and Great Basin Deserts. The death or displacement of individuals of some animal species as a result of site clearing and vehicle traffic would be unavoidable; however, changes in the regional population of any species would be undetectable.

No Federally endangered species are found on the site. The only Federally threatened species on the site is the desert tortoise (see Chapter 4, Section 4.1.4). Approximately 6 square kilometers (2.5 square miles or 1,500 acres) of desert tortoise habitat would be lost. This habitat is at the northern end of the range of the desert tortoise and is not designated critical habitat for the tortoise. The quantity of habitat that could be lost would be minimal in comparison to the range of the desert tortoise.

The U.S. Fish and Wildlife Service has issued a Biological Opinion (see Appendix O) stating reasonable and prudent measures and conditions that DOE would have to observe to protect the desert tortoise if the Proposed Action was implemented. DOE would adhere to all terms stated in the Biological Opinion, but, as the opinion acknowledges, individual tortoises could be killed inadvertently during site clearing, by vehicle traffic, or by predation from ravens. Preconstruction surveys, relocation of affected individuals, and adherence to conditions stated in the Biological Opinion would minimize, but not prevent, such deaths. Chapter 4, Section 4.1.4, discusses in detail the potential for loss of habitat or the deaths of individual members of this species. Chapter 9 (Sections 9.2.4.1 and 9.3.4.1) discusses mitigation measures to reduce potential impacts to the desert tortoise, including measures to locate facilities and roadways to avoid sensitive areas and measures to protect tortoises from construction impacts.

10.1.1.5 Cultural Resources

In the view of Native Americans, the implementation of the Proposed Action would further degrade the environmental setting. Even after closure and reclamation, the presence of the repository would, from the perspective of Native Americans, represent an irreversible impact to traditional lands.

NATIVE AMERICAN VIEW

A Native American view of facility and transportation route development, especially in remote areas such as Yucca Mountain and its surroundings, as expressed in the *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement* (DIRS 102043-AIWS 1998, pages 2-20 and 3-1), is that development of such facilities and routes inherently degrades the entire environment. This view is based on the concept that the earth, its waters, the air, and the sky are a whole and have a sacred integrity in their natural form. Chapter 4, Section 4.1.13, of this EIS presents an environmental justice discussion of this Native American perspective.

Some unavoidable adverse impacts could occur to archaeological sites and other cultural resources, although no such sites or culturally important artifacts have been found at the site of the proposed repository. There could be a loss of archaeological information due to illicit artifact collection. In addition, excavation activities could cause a loss of archaeological information. Similarly, the location of a solar power generating facility on the repository site, could affect archaeological sites. Chapter 3, Section 3.1.6, discusses the program DOE has in place to address and mitigate cultural resource impacts and issues during site characterization. DOE anticipates this program would continue through repository closure.

10.1.1.6 Socioeconomics

The construction, operation and monitoring, and closure of a repository at Yucca Mountain would result in increased employment and population, which would place increased demands on housing and public services, including schools. Nonetheless, these demands would be small in comparison to total employment, population, real disposable income, gross regional product, and public expenditures in the region of influence.

10.1.1.7 Occupational and Public Health and Safety

There would be a potential for injuries to or fatalities of workers from facility construction, including accidents and inhalation of cristobalite and erionite. Cristobalite and erionite are naturally occurring hazardous materials in the rock of Yucca Mountain. Engineering controls and training and safety programs would reduce but not eliminate the potential for injuries or fatalities to workers.

Short-term impacts during the operation and monitoring phase would present a potential for injuries or fatalities to workers from industrial accidents and exposure to radioactive materials. Engineering controls and training and safety programs would reduce but not eliminate the potential. There would also be a potential for injuries and fatalities during closure. The occupational and public health and safety discussion in Chapter 4 (Sections 4.1.7 and 4.1.8) provides details on the potential for worker injuries and fatalities. The potential for injury or death to members of the public from exposure to radioactive materials or industrial activity would be extremely small.

While there would be a potential for radioactive contamination of groundwater during the 10,000-year analysis period from materials stored at the proposed repository, there would be only a small potential for such contamination to produce long-term adverse health impacts in the surrounding region during this period, even when the potential for changing climate and seismic events is considered. Potential long-term impacts to human health from the repository in the far future would be dominated by impacts from radioactive materials dissolved or suspended in water pathways. The dose to the reasonably maximally exposed individual would depend on the distance from the repository and the uses made of the land and waters.

At the compliance point defined in Chapter 5 [36 degrees, 40 minutes, 13.6661 seconds North latitude in the predominant direction of groundwater flow (40 CFR Part 197)], the highest 95th percentile annual dose to the reasonably maximally exposed individual for the 10,000-year analysis period would be 0.0001 millirem. The highest chance of a latent cancer fatality to this hypothetical individual would be 4 in 1 billion (see Chapter 5, Section 5.4.2.1). A latent cancer fatality is a cancer fatality that could occur after and as a result of exposure to radionuclides from the repository and that would be in addition to cancer fatalities occurring from all other causes.

Expected doses and consequences to the population from exposure to radionuclides transported by groundwater from the repository were forecast for the 10,000-year analysis period. The 95th-percentile population dose over the 10,000-year period could be 0.04 person-rem over an assumed 70-year lifetime.

The estimated 95th-percentile number of latent cancer fatalities in the population during any 70-year lifetime would be 0.00002. Over the 10,000-year analysis period, the estimated number of latent cancer fatalities would be 0.0003 (see Chapter 5, Section 5.4.2.1). These consequences would be small.

DOE estimates that most waste packages would remain intact longer than 10,000 years. Current model simulations forecast that some packages would last more than 1 million years. The highest 95th-percentile peak annual dose to a hypothetical reasonably maximally exposed individual could be 620 millirem approximately 410,000 years in the future. The highest mean peak annual dose rate to a reasonably maximally exposed individual at 18 kilometers (11 miles) could be 150 millirem per year approximately 480,000 years in the future (see Chapter 5, Section 5.4.2.1). In the unlikely event of an igneous disruption of the repository, the probability-weighted peak mean annual dose resulting to an individual would be approximately 0.1 millirem.

As determined by a bounding analysis (see Appendix I, Section I.6), there would also be a potential that chromium releases could produce estimated peak concentrations during the first 10,000 years of 0.01 milligram per liter at 18 kilometers (11 miles). This value is approximately one-tenth of the Maximum Contaminant Level Goal in drinking water.

10.1.1.8 Utilities, Energy, and Materials

The construction, operation and monitoring, and closure of a repository at Yucca Mountain would result in irreversible commitments of energy (mostly electricity and petroleum products) and materials (mostly cement, steel, and copper). These commitments would not be large enough to affect national or regional supplies.

10.1.2 NATIONAL TRANSPORTATION ACTIONS

10.1.2.1 Air Quality

To determine if pollutants of concern from national transportation by truck and rail would degrade air quality in nonattainment areas outside Nevada, DOE reviewed traffic volumes in nonattainment areas (see Chapter 6, Section 6.2). From this review DOE determined that the number of shipments to Yucca Mountain would be very small in relation to normal traffic volumes in the nonattainment areas studied, and that, therefore, impacts to air quality in these areas from repository-related shipments would be very small.

10.1.2.2 Occupational and Public Health and Safety

Certain adverse impacts to workers and the public from the transportation of spent nuclear fuel and high-level radioactive waste would be unavoidable. The loading and transportation of these materials would have the potential to affect workers and the public through industrial accidents, exposure to radiation and vehicle emissions, and through traffic accidents. This EIS evaluates two transportation scenarios—one in which DOE would transport the materials mostly by legal-weight truck and the other in which it would transport the materials mostly by rail. DOE estimates that the transportation of spent nuclear fuel and high-level radioactive waste nationally, including in Nevada, in the mostly legal-weight truck scenario could cause as many as 21 fatalities among workers and the public over the 24 years of the Proposed Action. These fatalities would include fatalities in industrial accidents, traffic fatalities, latent cancer fatalities caused by exposure to radiation, and health effect fatalities caused by exposure to vehicle emissions. DOE estimates that transportation mostly by rail could cause between 8 and 14 fatalities among workers and the public, including fatalities from upgrading and maintaining highways and constructing an intermodal transfer facility or constructing a branch rail line in Nevada as well as fatalities from operations over 24 years. These fatalities would also result from industrial accidents, vehicle crashes, radiation exposure, and exposure to vehicle emissions.

10.1.3 NEVADA TRANSPORTATION ACTIONS

This section summarizes unavoidable adverse impacts associated with the transportation of spent nuclear fuel and high-level radioactive waste and with the construction and operation of transportation facilities and routes in Nevada. Chapter 6 (Sections 6.1.2 and 6.3) provides more detailed discussions.

10.1.3.1 Land Use

Constructing and operating a new branch rail line would result in unavoidable changes to present land uses and control of the lands affected directly. The range of potentially affected uses includes grazing, wildlife habitat and management areas, mining, wilderness, Native American tribal uses, recreation, utility corridors, lands leased for oil and gas development, and military lands. Present uses of adjoining lands could also be affected to some extent. Each of the five corridors for a branch rail line encompasses a range of different land uses and surface features. If the choice was to construct a new branch rail line, the selection of a specific corridor would determine the land actually taken and the extent of impacts to land uses along that corridor. Land disturbed for a specific corridor implementing alternative could vary from 5.1 to 19.2 square kilometers (1,300 to 4,700 acres). Most land along the corridors under consideration is government administered or controlled. The Valley Modified Corridor crosses two Wilderness Study Areas. The Steiner Creek Alternate for the Carlin Corridor passes close to or encroaches on the Simpson Park Wilderness Study Area, depending on alignment. The Bonnie Claire Alternate for the Carlin and Caliente Corridors crosses lands of the Timbisha Shoshone Tribe near Scottys Junction, Nevada. The Caliente Corridor crosses a portion of the South Reveille Wilderness Study Area. The Caliente Corridor and the Caliente-Chalk Mountain Corridor pass through or encroach on the Weepa Springs Wilderness Study Area, depending on alignment.

Routes for heavy-haul or legal-weight trucks would follow existing highways and could require establishing and using access roads to obtain construction materials and additional land disturbance for road widening. Building and operating an intermodal transfer station would result in unavoidable changes of land use and ownership. The land for an intermodal transfer station could be public or private. Actual land uses lost would depend on the site and route selected. DOE expects that the total land disturbance for any implementing alternative for the construction of an intermodal transfer station and upgrades to existing highways could be as much as 3.5 square kilometers (about 860 acres). For heavy-haul truck routes originating at Caliente, an additional 0.04 square kilometer (10 acres) could be required for a midroute stop. A further 0.04 square kilometer could be required for the construction of a highway segment near Beatty, Nevada.

In some instances transportation facilities could remain in place to serve other purposes after DOE had ended use. Similarly, affected land could revert to other uses after the end of transportation activities and the removal of facilities.

10.1.3.2 Air Quality

The potential construction of the Valley Modified Alternate branch rail line or upgrades to roads to accommodate heavy-haul trucks in the Las Vegas Valley air basin, which is in nonattainment with Environmental Protection Agency standards for emissions of PM_{10} and carbon monoxide, could affect the ability of local governments to meet air quality goals.

The operation of a branch rail line or an intermodal transfer station and associated heavy-haul truck routes would lead to releases of pollutants, but these would be below thresholds of concern.

Legal-weight truck shipments through the Las Vegas Valley air basin would also emit pollutants. However, the number of legal-weight truck shipments would be less than 1 percent of all truck traffic in the area and would not contribute discernibly to sources of air pollution.

10.1.3.3 Hydrology

The construction of a branch rail line or the upgrading of roads to accommodate heavy-haul transportation in Nevada would involve the unavoidable adverse impact of altering natural surface-water drainage patterns. Any of the Nevada transportation corridors would cross a number of natural drainage channels. Upgrade activities for a route to be used by heavy-haul trucks would involve the extension of existing drainage control structures as necessary to support the road upgrades. In this case, there would be minor changes to drainage channels already altered to some extent by the original road construction. The construction of a branch rail line would require alterations to many natural drainage areas along the line. Bridges and culverts would be used as necessary to cross streams, creeks, or, most predominantly, washes of any size. These structures would be built to accommodate a 100-year flow in the channels; the resulting drainage alteration would be confined to relatively small areas. Construction could alter small drainage channels or washes more because the railway design could call for the collection of some channels to a single culvert. At the end of the period during which DOE would transport spent nuclear fuel and high-level radioactive waste to the repository, the Department could remove facilities built for transportation and land recovery could begin, or it could use the facilities for other purposes. Appendix L contains a floodplain/wetlands assessment that presents a comparison of what is known about the floodplains, springs, and riparian areas along the five alternative rail routes and at the three alternative intermodal transfer station sites with their five associated heavy-haul truck routes.

In addition, the construction of a branch rail line or upgrades to a route for heavy-haul trucks would involve the withdrawal and use of water from groundwater resources. In many areas that a branch rail line would cross, other uses or commitments of groundwater resources approach or exceed the perennial yield of the underlying groundwater basins. The Nevada State Engineer has identified these areas as Designated Groundwater Basins, which the State watches for potential groundwater depletion. DOE would apply for State water appropriations for withdrawal of groundwater from any wells it developed to construct a branch rail line or would acquire water from appropriated sources and ship the water to its construction sites.

10.1.3.4 Biological Resources and Soils

Unavoidable adverse impacts to biological resources from transportation in Nevada could occur as a result of habitat loss and the deaths of small numbers of individuals of species along transportation routes. Habitat loss would be associated with the construction of either a new rail line or an intermodal transfer station and upgrades to existing highways. This loss would occur in widely distributed land cover types, and would include the loss of a small amount of desert tortoise habitat and the deaths of a small number of tortoises. The deaths of individual members of a species as a result of construction activities or from vehicle traffic would be unlikely to produce detectable changes in the regional population of a species.

Transportation route construction or upgrades would subject disturbed soils to increased erosion for at least some of the construction phase. The recovery of these disturbed areas to predisturbance conditions would occur with the passage of time. Transportation facilities such as a branch rail line could be used for nonrepository-related purposes, potentially extending their useful life beyond the period needed for the Proposed Action. The removal of transportation facilities after the end of their useful life would assist habitat recovery.

Disturbance of habitat could lend to intrusion of invasive species. These species would compete with native species and could become dominant in areas adjacent to the routes. In addition, they could increase the risk of fire in areas adjacent to the routes.

10.1.3.5 Cultural Resources

Some unavoidable impacts could occur to archaeological sites and other resources as a result of the construction of a rail line or the upgrade of a highway to heavy-haul capability. The potential for impacts to specific resources cannot be identified before final surveys and actual construction. An agreement now in effect between DOE and the Advisory Council on Historic Preservation for repository site characterization could serve as a model for an agreement to protect archaeological sites and other resources along transportation corridors. In addition, a number of statutes provide protective frameworks (see Chapter 11). Nevertheless, there would be a potential for grading and other construction activities to degrade, cause the removal of, or alter the setting of archaeological sites or other cultural resources. Although mitigated to some extent by worker education programs, there could be some loss of archaeological information due to the illicit collection of artifacts. In addition, excavation activities could cause loss of archaeological information.

10.1.3.6 Socioeconomics

The construction of a branch rail line in Nevada or of an intermodal transfer station and upgrades to associated highways for heavy-haul trucks would result in the irreversible use of economic resources. In addition, economic activity spawned by construction and subsequent operations would affect the availability and cost of resources used for other purposes in Nevada. Increased employment and population would place increased demands on housing and public services, including schools. Nonetheless, overall socioeconomic impacts in the region of influence would be small in comparison to total employment, population, real disposable income, Gross Regional Product, and public expenditures.

10.1.3.7 Occupational and Public Health and Safety

Certain adverse impacts to workers and the public from the construction and operation of the rail and heavy-haul implementing alternatives would be unavoidable. Table 10-1 presents potential health and safety impacts to workers and the public (fatalities) during construction and operations for each implementing alternative.

Table 10-1. Unavoidable adverse impacts from rail and heavy-haul truck implementing alternatives.[a]

	Construction (worker and public fatalities)	Operations (worker and public fatalities)
Rail		
Caliente	1.6	1.5
Carlin	1.4	1.6
Caliente-Chalk Mountain	1.0	1.4
Jean	0.89	1.3
Valley Modified	0.5	1.1
Heavy-haul truck[b]		
Caliente	1.8	4.5
Caliente/Chalk Mountain	0.74	3.8
Caliente/Las Vegas	1.3	4.3
Apex/Dry Lake	0.6	3.0
Sloan/Jean	0.6	3.1

a. Source: Chapter 6, Sections 6.3.2.2 and 6.3.3.2.
b. Includes intermodal transfer station impacts.

The transportation of spent nuclear fuel and high-level radioactive waste would have the potential to affect workers and the public in Nevada through exposure to radiation and vehicle emissions and through traffic accidents. This EIS evaluates two transportation scenarios—one in which DOE would transport the materials mostly by legal-weight truck and the other in which it would transport the materials mostly by rail to Nevada and then to the repository by either heavy-haul truck or a branch rail line. DOE estimates that the transportation of spent nuclear fuel and high-level radioactive waste in the mostly legal-weight truck scenario could cause approximately 1.4 fatalities among workers and the public in Nevada as a result of exposure to radiation, vehicle emissions, and accidents over the course of 24 years. Over the same period, DOE estimates that transportation using a branch rail line in Nevada could cause up to 3.1 fatalities among workers and the public, while use of heavy-haul trucks in Nevada could result in up to 6.3 worker and public fatalities.

10.1.3.8 Aesthetics

The construction of a branch rail line in the Jean Corridor (Wilson Pass Option) would lead to a change to the aesthetic resource value of lands along the western slopes of the Spring Mountains, which the Bureau of Land Management classifies as a Class II visual resource. The construction of an intermodal transfer station near Caliente, Nevada, could affect the aesthetic value of lands in the entrance portion of the Kershaw-Ryan State Park until the station was removed.

10.1.3.9 Noise and Vibration

The long-term use of a branch rail line in any of the five rail corridors in Nevada would lead to an increase in ambient noise from periodically passing trains in areas of the State that are currently mostly uninhabited. This could affect solitude which the American Indian Writers Subgroup identified as essential for meditation and prayer. In addition, it could degrade the recreation values of the areas for individuals who seek primitive outdoor experiences. Noise from trains could be noticeable as new noise in residential areas near a potential branch rail line.

For Nevada transportation implementing alternatives that would use heavy-haul trucks, the noise from the trucks and the operation of an intermodal transfer station would be only slightly discernable above the noise of normal traffic and nearby industrial or railroad noise.

10.1.3.10 Utilities, Energy, and Materials

The construction of a branch rail line or upgrades to highways for use by heavy-haul trucks and construction of an intermodal transfer station would result in irreversible commitments of energy (mostly petroleum products) and materials (steel, concrete, and rock). These commitments would not be large enough to affect national or regional supplies.

10.1.3.11 Waste Management

The construction and operation of any of the 10 Nevada heavy-haul truck or rail implementing alternatives would generate small amounts of construction debris, sanitary solid waste, sanitary sewage, and hazardous waste. This waste would be managed by recycling, placement in permitted landfills, reuse or, in the case of sanitary sewage, onsite treatment and disposal. Waste would be managed in accordance with applicable requirements to minimize the possibility of adverse impacts to the environment. A small amount of low-level radioactive waste could be generated at an intermodal transfer station under the heavy-haul truck implementing alternative and would be disposed of in accordance with applicable regulations. The quantities of waste to be disposed of would not affect the availability of waste disposal resources for other users.

DOE would use excavated soil and rock from the construction of a branch rail line and the State of Nevada would use material from existing borrow areas and roadway excavations (highway upgrades) for fill to the extent feasible. However, some previously undisturbed areas could be covered with excavated soil and rock. To place and stabilize these materials, DOE would use approved practices that would minimize affected land areas and reduce potential impacts to biological resources and surface-water resources.

10.2 Relationship Between Short-Term Uses and Long-Term Productivity

The Proposed Action could require short-term uses of the environment that would affect long-term environmental productivity. This section describes possible consequences to long-term productivity from those short-term environmental uses.

The EIS analysis identified two distinct periods for the evaluation of the use of the environment by the Proposed Action:

- A period of 115 to 341 years for surface activities consisting of construction, operation and monitoring, and closure of the proposed repository. DOE activities during this period would include construction of facilities, receipt and emplacement of spent nuclear fuel and high-level radioactive waste, recovery of recyclable materials, ventilation of subsurface emplacement areas, decontamination, closure of surface and subsurface facilities, reclamation of land, and long-term monitoring. Sections 10.1.1.1 through 10.1.1.6 describe the unavoidable impacts that could occur during this period. This period would be the only time during which DOE would actively use the affected lands and the only time during which activities would involve the surface of the land used for the repository.

- The balance of a 10,000-year period would be for the evaluation of consequences from the disposal of spent nuclear fuel and high-level radioactive waste.

In general, transportation and disposal activities associated with the proposed repository would benefit long-term productivity by removing spent nuclear fuel and high-level radioactive waste from 72 commercial and 5 DOE sites around the country. In addition, removing these materials from existing sites would also free people and resources committed—now and in the future—to monitoring and safeguarding these materials for other potentially more productive activities. Removal could create conditions that would enable the initiation of other productive uses at the commercial and DOE sites. Finally, disposing of spent nuclear fuel and high-level radioactive waste in the proposed repository would provide a long-term global benefit by isolating the materials from concentrations of human population and human activity, thereby reducing the potential for sabotage.

10.2.1 YUCCA MOUNTAIN REPOSITORY

This section summarizes the relationship between short-term uses of land and resources and long-term land and resource productivity for the construction, operation and monitoring, closure, and long-term performance of the proposed repository. The terms "short-term" and "long-term" commonly used in National Environmental Policy Act analyses do not have a consistent duration in this section. For the analysis of impacts associated with repository activities, *short-term* refers to the time from the start of construction to the end of relevant surface and subsurface human activity, which DOE anticipates to range from 115 to 341 years. *Long-term* refers to the time between the end of relevant surface and subsurface human activity and the time when environmental resources have recovered from the potential for impacts and are again productive, or a maximum of 10,000 years. For transportation, *short-term* refers to the time of construction or actual transportation, as appropriate. *Long-term* refers to the time from the end of the short-term period to the time of environmental recovery. *Productivity* refers to the ability of an element of the environment to generate crops, provide habitat, or otherwise serve as a medium for the creation of value.

10.2.1.1 Land Use

From the start of construction through the 10,000-year period, the construction, operation and monitoring, and closure of the proposed repository would deny other users the use of the Yucca Mountain vicinity for other purposes. Chapter 4, Section 4.1.1, discusses the long-term uses of land. Conversely, a repository at Yucca Mountain would enable consideration of other uses for the sites where spent nuclear fuel and high-level radioactive waste are being stored and the land buffering those sites. Many present storage sites are in locations that would permit a wider range of alternative uses than does Yucca Mountain.

10.2.1.2 Hydrology

The proposed repository would be in a terminal basin that is hydrologically isolated and separated from other bodies of surface and subsurface water; that is, once water enters the basin it can leave only by evapotranspiration. As explained in Section 10.1.1.3, there would be a potential for materials disposed of at the proposed Yucca Mountain Repository to reach groundwater at some time between several thousand years and several hundred thousand years. If such contamination reached groundwater in the accessible environment, and if the groundwater contamination exceeded applicable regulatory requirements, there could be an attendant loss of productivity for the affected groundwater and for surface waters in the basin that the groundwater supplied. Conversely, the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would free a wide range of major and minor water bodies throughout the United States from the potential threat of radioactive contamination from the materials at the present storage sites.

10.2.1.3 Biological Resources and Soils

Short-term uses that could cause impacts to biological resources and soils would be associated with the construction, operation and monitoring, and closure of the repository; those activities could lead to long-term productivity loss in disturbed areas. This loss would be limited to less than 6.0 square kilometers (1,500 acres) of widely distributed habitats adjacent to existing disturbed areas. Biological resources would be affected directly by land disturbances. The overall impact to populations of species would be limited because the area disturbed and the number of individual animals lost would be small in relation to the regional availability.

Long-term productivity loss for soils would be limited to areas affected by land disturbances. These areas would be revegetated after the completion of closure activities. Revegetation would be accomplished through the reclamation of disturbed sites using surface soils stockpiled during construction, reseeding, and similar activities that would enhance recovery. Chapter 4, Section 4.1.4, contains more detail on productivity losses and reclamation. The disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain would remove these materials from proximity to biota near the present storage sites across the United States.

10.2.1.4 Occupational and Public Health and Safety

A repository at Yucca Mountain would be likely to have a positive effect on the nationwide general occupational and public health because of the cessation of doses to workers at the present storage sites and because the spent nuclear fuel and high-level radioactive waste would be substantially more isolated from concentrations of people and from pathways to concentrations of people.

10.2.2 TRANSPORTATION ACTIONS

The construction of a rail line or an intermodal transfer station and improvements to existing highways, all short-term uses, could lead to a long-term loss of productivity in disturbed areas along the routes. In the context of transportation, *long-term* refers to the period of environmental recovery after the end of the construction period or the active use of a transportation route for repository purposes. A route could be used for repository purposes from 10 to approximately 30 years.

The land cover types along any route are widely distributed in the region. A loss of vegetation from a disturbed area along a route would have little effect on the regional productivity of plants and animals.

Productivity loss for soils would be limited to areas affected by land clearing and construction. These areas would not be available for revegetation and habitat for some time. Disturbed areas would recover, however, and eventually would return to predisturbance conditions, although the process of recovery would be slow in the arid environment. Chapter 6 contains more data on transportation.

The construction of a rail line, if the line were also used for nonrepository uses, could result in productivity benefits for Nevada by increasing transportation opportunities, lowering transportation costs, reducing accidents, and lowering nitrogen oxides, carbon monoxide, and other gaseous criteria pollutant emissions by diverting transportation from highway to rail.

The major long-term consequence of transporting spent nuclear fuel and high-level radioactive waste to the repository would be the permanent consolidation of these materials in an isolated location away from concentrations of people and without exposure pathways to concentrations of people.

10.3 Irreversible or Irretrievable Commitment of Resources

The Proposed Action would involve the irreversible or irretrievable commitment of land, energy, and materials. The commitment of a resource is irreversible if its primary or secondary impacts limit future options for the resource. An irretrievable commitment refers to the use or consumption of resources that are neither renewable nor recoverable for later use by future generations. Construction, operation and monitoring, and eventual closure of a repository at Yucca Mountain would result in a permanent commitment of land, groundwater, surface, subsurface, mineral, biological, soil, and air resources; materials such as steel and concrete; and consume energy in forms such as gasoline, diesel fuel, and electricity. Water use would support construction, operation and monitoring, and closure actions, and options for using groundwater could become limited if there was contamination from radionuclides. There would be an irreversible and irretrievable commitment of associated natural resource services such as uses of land and habitat productivity.

10.3.1 YUCCA MOUNTAIN REPOSITORY

The construction, operation and monitoring, closure, and long-term performance of the Yucca Mountain Repository would result in the permanent commitment of the surface and subsurface of Yucca Mountain and the permanent withdrawal of lands from public use. Because of the remote location of Yucca Mountain, the lack of present uses of the land, the terminal and isolated nature of the water basin, and the limited amounts of materials and energy required for the repository in comparison to the supply capability of the regional and national economies, the irreversible and irretrievable commitments of resources for repository-related activities would be small.

Mitigation approaches that would involve the excavation of archaeological sites to prevent degradation by construction activities would destroy the contexts of those sites and reduce the finite number of such resources in the region. DOE expects that its activities at the proposed repository would affect no more than a minimal number of such sites. The Department would use state-of-the-art mitigation techniques on the Yucca Mountain Project.

Electric power, fossil fuels, and construction materials would be irreversibly committed to the project. Most of the steel used for the surface facilities would be recyclable and, therefore, not an irreversible or irretrievable commitment. Some copper and steel in the ramps and access mains to subsurface facilities would be recyclable, while some in the emplacement drifts would be irreversibly and irretrievably lost. Some steel, such as rebar, would be difficult to recycle. The quantity of resources consumed would be small in comparison to their national consumption or their availability to consumers in southern Nevada. These quantities are described in Chapter 4. To the extent that there is value in spent nuclear fuel or high-level radioactive waste, that value would be committed to the repository.

Aggregate would be crushed as required and mixed in concrete for the cast-in-place and precast concrete structures and liners that would be used in the repository. The amount of sand and aggregate could range from 1.2 million to 2.54 million metric tons (1.3 to 2.8 million tons). If Yucca Mountain tuff was used as the aggregate component of the subsurface concrete, the amount crushed and used as aggregate would be less than 15 percent of the total excavated from the drifts (see Chapter 4, Section 4.1.11).

Repository closure would make the energy content of uranium and plutonium in spent nuclear fuel unavailable for use by future generations.

10.3.2 TRANSPORTATION ACTIONS

The construction of a rail line or an intermodal transfer station would result in an irretrievable but not irreversible commitment of resources. Many resources could be retrieved at a later date through such actions as removing roadbeds, revegetating land, and recycling materials. Land uses would change along the selected transportation corridor during repository construction, operation and monitoring, and closure, thereby limiting or eliminating other land uses for that period. At the end of that period, however, land along the corridor could revert to public or private ownership.

Mitigation approaches involving the recovery of archaeological resources before construction activities degraded the sites would reduce the finite number of such resources in the Yucca Mountain region and destroy the context of sites. DOE would use state-of-the-art mitigation techniques during the construction of a rail corridor or an intermodal transfer station or the modification of roadways to accommodate heavy-haul trucks. Heavy-haul construction would be likely to generate only minimal impacts to cultural resources because construction would largely involve modifications to existing roads.

DOE would use about 500 to 700 million liters (132 to 185 million gallons) of fossil fuel from the nationwide supply system to transport spent nuclear fuel and high-level radioactive waste to the repository. The analysis in Chapter 6 (Sections 6.1.2.10, 6.3, 6.3.2.1, 6.3.2.2, 6.3.3.1, and 6.3.3.2), evaluates fuel use for the different transportation scenarios. The amount used would be a very small fraction of a percent of the Nation's supply over the period of fuel use.

The manufacture of casks and containers would require commitment of aluminum, chromium, copper, depleted uranium, lead, molybdenum, nickel, and steel. The required amounts of these materials, expressed as percentages of U.S. production, would be low with the exception of nickel, which would require approximately 8.2 percent of annual U.S. production.

REFERENCES

102043	AIWS 1998	AIWS (American Indian Writers Subgroup) 1998. *American Indian Perspectives on the Yucca Mountain Site Characterization Project and the Repository Environmental Impact Statement.* Las Vegas, Nevada: Consolidated Group of Tribes and Organizations. ACC: MOL.19980420.0041.
154659	BSC 2001	BSC (Bechtel SAIC Company) 2001. *FY01 Supplemental Science and Performance Analyses, Volume 2: Performance Analyses.* TDR-MGR-PA-000001 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010724.0110.

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11. STATUTORY AND OTHER APPLICABLE REQUIREMENTS

The U.S. Department of Energy (DOE or the Department) has conducted site characterization activities in accordance with requirements of applicable laws and regulations and a range of permits and approvals that regulate the various aspects of the activities. The Department has successfully met environmental protection standards for its site characterization activities by developing a comprehensive approach to environmental compliance that ensures adherence to Federal and state requirements. It has implemented specific environmental compliance programs for pollution prevention, protection of cultural resources, and protection of threatened or endangered species. In its future actions involving Yucca Mountain, DOE will continue to comply with applicable Federal and state environmental requirements and with the conditions of the permits and approvals that might be required to conduct its activities, and will continue its involvement with tribal governments in accordance with Executive Orders, laws, and customs, and as based on relationships established by treaties.

This chapter identifies major requirements that could be applicable to the Proposed Action, which is to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. Section 11.1 lists statutory and regulatory provisions that set requirements potentially applicable to siting a monitored geologic repository. Section 11.2 summarizes statutes and regulations that set environmental protection requirements that could apply to a repository at Yucca Mountain. Section 11.3 contains a list of DOE Orders that could apply to activities related to the proposed repository. Section 11.4 contains a list of potentially applicable requirements compiled by the DOE Office of Civilian Radioactive Waste Management.

Table 11-1 lists potential new permits, licenses, and approvals that DOE could need for construction, operation, and closure of the Yucca Mountain Repository.

11.1 Statutes and Regulations Establishing or Affecting Authority To Propose, License, and Develop a Monitored Geologic Repository

Nuclear Waste Policy Act of 1982, as amended (42 U.S.C. 10101-10270)

The Nuclear Waste Policy Act, as amended in 1987 (NWPA), directs DOE to characterize and evaluate the suitability of only Yucca Mountain in southern Nevada as a potential site for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste. After considering the suitability of the site and other information, the Secretary may then recommend approval of the site to the President. Further, the NWPA states that an environmental impact statement (EIS) must accompany any recommendation that the President approve the site for a repository. If the President recommends the Yucca Mountain Site to Congress and the designation takes effect, the NWPA provides that the Secretary of Energy must submit an application for construction authorization to the U.S. Nuclear Regulatory Commission not later than 90 days after the date on which the site designation is effective.

The NWPA directs the U.S. Environmental Protection Agency to promulgate generally applicable standards for protection of the environment from offsite releases from radioactive material in repositories. In addition, it requires the Nuclear Regulatory Commission to consider and approve or disapprove an application (if DOE submits one) for authorization to construct a repository for these materials based on Commission standards, which are to be consistent with the Environmental Protection Agency standards. In 1983, the Nuclear Regulatory Commission promulgated licensing requirements (10 CFR Part 60) that contain general criteria governing the issuance of a construction authorization and license for a geologic repository. These requirements would allow DOE to develop a repository for the receipt and disposal of spent nuclear fuel and high-level radioactive waste and would establish conditions under which DOE could receive and possess source, special nuclear, and byproduct material at a geologic repository. The

Table 11-1. Permits, licenses, and approvals needed for a monitored geologic repository.

	Activity	Regulatory action	Statute or regulation	Agency(ies)
1.	Disposal of spent nuclear fuel and high-level radioactive waste	Final public health and environmental protection standards	40 CFR[a] Part 197	Environmental Protection Agency
2.	Repository construction, operation, and closure	Construction authorization, license to operate and monitor, and license for closure	10 CFR Part 63	Nuclear Regulatory Commission
3.	Site suitability	Criteria and methodology for determining suitability of Yucca Mountain Site	10 CFR Part 963	Department of Energy
4.	Repository construction, operation, and closure	Withdrawal of Land from Public Use	Future Congressional Bill needed to authorize withdrawal, 43 CFR Part 2300	Congress, Bureau of Land Management
5.	Air emissions	Approvals for New Sources of Toxic Air Pollutants	40 CFR Parts 61 and 63	Environmental Protection Agency
			NAC[b] 445B.287 *et seq.*	Nevada Division of Environmental Protection
6.	Air emissions	Air Quality Operating Permit	NAC 445B.287 *et seq.*	Nevada Division of Environmental Protection
7.	Air emissions	National Emission Standards for Hazardous Air Pollutants Subpart H (Radionuclides)	40 CFR Part 61	Environmental Protection Agency
			10 CFR Part 20	Nuclear Regulatory Commission
		National Primary and Secondary Ambient Air Quality Standards	40 CFR Part 50	Environmental Protection Agency
8.	Certification of facilities	Certification of Air and Water Pollution Control Facilities	40 CFR Part 20	Environmental Protection Agency
9.	Drinking water	Water System Operating Permit	NAC 445A.070 *et seq.*	Nevada Health Division
10.	Effluents	Stormwater Discharge	40 CFR Part 122	Environmental Protection Agency
			NAC 445A.070 *et seq.*	Nevada Division of Water Planning
11.	Effluents	National Pollutant Discharge Elimination System	40 CFR Part 122	Environmental Protection Agency
		State Water Pollution Control Permit	NAC Chapter 445A	Nevada Division of Water Planning, Nevada Division of Environmental Protection
12.	Excavation; facility construction	Cultural Resource Review Clearance, Section 106 Agreement	36 CFR Part 800	Advisory Council on Historic Preservation, State Historic Preservation Officer
13.	Excavation; facility construction	Permit to Proceed (Objects of Antiquity)	36 CFR Part 296 43 CFR Parts 3 and 7	Department of the Interior
14.	Excavation; facility construction	Permit for Excavation or Removal of Archaeological Resources	16 U.S.C.[c] 470 *et seq.*	Department of the Interior, affected Native American Tribes
15.	Facility construction	Free-Use Permit	43 CFR Part 3620	Bureau of Land Management, Forest Service
16.	Facility construction	Permit for the discharge of dredged or fill materials to Waters of the United States	Clean Water Act, Section 404	U.S. Army Corps of Engineers
17.	Transportation to Facility	Right-of-way reservations	43 CFR 2800	Bureau of Land Management
18.	Facility construction and operation	Endangered Species Consultation	50 CFR 402.6	Fish and Wildlife Service
19.	Materials storage	Hazardous Materials Storage Permit	NAC Chapters 459 and 477	Nevada State Fire Marshal

a. CFR = Code of Federal Regulations.
b. NAC = Nevada Administrative Code.
c. U.S.C. = United States Code.

requirements in 10 CFR Part 60 do not apply to any nonrepository activities licensed under other parts of Title 10 of the Code of Federal Regulations.

Congress originally passed the Nuclear Waste Policy Act in 1982. The 1982 legislation directed the Secretary of Energy to recommend potential sites to the President for possible characterization as geologic repositories, and it directed the President to select sites for characterization. The Nuclear Waste Policy Act also required the Secretary of Energy to issue general guidelines for use in recommending potential geologic repository sites for detailed site characterization. DOE issued those guidelines in 1984 (10 CFR Part 960) and applied them when it nominated five sites as suitable for characterization and recommended characterization of three of the sites.

DOE decided to include in the general guidelines a process for evaluating the data obtained from site characterization activities to be used in determining whether a site should be recommended for the development of a geologic repository. In 1996, DOE proposed to clarify and focus its 10 CFR Part 960 guidelines (to be codified at 10 CFR Part 963), but never issued those guidelines as final. In 1999, DOE proposed further revisions to the draft 10 CFR Part 963 guidelines (64 *FR* 67054). DOE has since finalized these changes and 10 CFR Part 963 has been promulgated (66 *FR* 57297). In the Site Recommendation, if any, DOE will consider these finalized guidelines.

Section 116(c) of the NWPA establishes a procedure by which DOE can consider and, if appropriate, address a broad array of considerations. The State of Nevada or an affected unit of local government can describe impacts that are likely to result from site characterization in a report and submit it to the Secretary of Energy. Section 116 of the NWPA allows DOE to consider these impacts as a basis for DOE providing technical or financial assistance. In contrast to the National Environmental Policy Act process, a Section 116(c) determination of impact assistance is not tied to an extensive body of past precedent or regulatory interpretations. DOE has broad discretion under Section 116(c) to consider impacts that the State of Nevada or an affected unit of local government might identify.

Energy Policy Act of 1992 (42 U.S.C. 10101 *et seq.*)

In the NWPA, Congress directed the Environmental Protection Agency to establish standards to protect the general environment from offsite releases from radioactive materials in repositories. The NWPA also directed the Nuclear Regulatory Commission to issue technical requirements and criteria that it will apply in approving or disapproving any applications regarding repositories. In 1992, Congress passed the Energy Policy Act, modifying the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission with respect to the proposed repository at Yucca Mountain. Section 801(a) of the Energy Policy Act directed the Environmental Protection Agency to (1) retain the National Academy of Sciences to make findings and recommendations on reasonable public health and safety standards for Yucca Mountain, and (2) establish Yucca Mountain-specific standards based on and consistent with the National Academy of Science’s findings and recommendations. Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to modify its technical requirements and criteria for geologic repositories to be consistent with the site-specific Yucca Mountain standard (40 CFR Part 197) established by the Environmental Protection Agency. Section 801(c) of the Energy Policy Act requires that DOE continue its oversight of the Yucca Mountain site after closure to prevent: (1) Unreasonable risk of breaching the repository’s barriers, and (2) Increasing the exposure of individual members of the public to radiation beyond allowable limits. The National Academy of Sciences issued its findings and recommendations in a 1995 report (DIRS 100018-National Research Council 1995, all).

Environmental Radiation Protection Standards for Yucca Mountain, Nevada (40 CFR Part 197)

In response to the Energy Policy Act of 1992, the Environmental Protection Agency has established Yucca Mountain-specific environmental standards for radioactive material stored at or disposed of in the Yucca Mountain site and for disposing of radioactive material in a Yucca Mountain repository (40 CFR

Part 197; see Table 11-1, item 1). The Environmental Protection Agency provisions set public health and environmental radiation protection standards.

As part of its evaluation of the potential for public health and environmental impacts, DOE measured the short-term and long-term performance of the repository system by comparing the volume and dispersion of analyzed releases against the 40 CFR Part 197 requirements as the Nuclear Regulatory Commission has adopted those requirements. Table 11-2 provides information on the 40 CFR Part 197 standards.

The disposal standards also include limits on radionuclides and types of radiation that releases from the repository could cause in groundwater during the 10,000-year period. The standards further require DOE to calculate the peak dose to the reasonably maximally exposed individual that would occur beyond 10,000 years but within the period of geologic stability and to include the results in this EIS.

Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain (10 CFR Part 63)

The U.S. Nuclear Regulatory Commission has established licensing regulations for disposal of spent nuclear fuel and high-level radioactive waste in the proposed geologic repository at Yucca Mountain, Nevada (10 CFR Part 63; see Table 11-1, item 2). The regulations establish site-specific technical requirements and criteria governing construction, operations and monitoring, closure, and long-term performance of the repository. If DOE submits appropriate applications, the Commission must use the requirements and criteria in 10 CFR Part 63 to determine whether to authorize the Department to construct a repository at Yucca Mountain, to license DOE to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to authorize DOE to close and decommission such a repository. To gain approval of a licensing application, the DOE repository design for Yucca Mountain must meet Nuclear Regulatory Commission requirements, including requirements for demonstrating compliance with the Environmental Protection Agency standards set forth at 40 CFR Part 197.

Title 10 CFR Part 63 includes the specification of overall performance objectives to protect the public health and safety during preclosure and postclosure phases of the repository. The technical criteria require that DOE demonstrate compliance with these overall performance objectives through an integrated safety analysis of preclosure operations, and through a performance assessment for long-term, postclosure performance. The criteria also address requirements for natural and engineered barriers, licensing procedures, public participation criteria, records and reporting, monitoring and testing programs, performance confirmation, quality assurance, personnel training and certification, and emergency planning. The criteria apply specifically and exclusively to the proposed repository at Yucca Mountain.

Yucca Mountain Site Suitability Guidelines (10 CFR Part 963)

The U.S. Department of Energy has set forth guidelines at 10 CFR Part 963 (see Table 11-1, item 3) to establish methods and criteria for determining the suitability of the Yucca Mountain site for the location and development of a geologic repository. The suitability determination is necessary to complete DOE's site characterization program activities required under section 113(b) of the Nuclear Waste Policy Act.

The guidelines focus on the criteria and methodology to be used for evaluating relevant geological and other related aspects of the Yucca Mountain site in assessing site suitability. The criteria and methodology are consistent with the latest scientific and analytical techniques and with the Nuclear Regulatory Commission's requirements set forth at 10 CFR Part 63 and the Environmental Protection Agency's standards established at 40 CFR Part 197. The guidelines consider the preclosure and postclosure periods, and are specific to Yucca Mountain.

Table 11-2. Title 40 CFR Part 197, Public Health and Environmental Protection Standards.

Component	Storage regulations	Disposal regulations
Individual Protection Standard[a]	150 microsieverts (15 millirem)[b]	150 microsieverts (15 millirem)[b]
Human Intrusion Standard	N/A[c]	150 microsieverts (15 millirem)[b]
Groundwater Protection Standard	N/A	• For combined radium-226 and radium-228, 5 picocuries per liter, including background radiation • For gross alpha activity (including radium-226 but excluding radon and uranium), 15 picocuries per liter, including background radiation • For combined beta- and photon-emitting radionuclides, 40 microsieverts (4 millirem) per year to the whole body or any organ, based on drinking 2 liters of water per day from the representative volume, not including background radiation
Applicable period	Construction, operation and monitoring, closure until repository is sealed	10,000 years after repository is sealed
Standards apply to	All members of the public	Reasonably maximally exposed individual[d]
Location where compliance is assessed	Anywhere in the general environment	The location where projected concentrations would be highest and that is no closer to the repository than the edge of the controlled area
Geographic scope of standards	Everywhere other than the Yucca Mountain site, the Nellis Air Force Range, and the Nevada Test Site	Everywhere outside the surface and subsurface of the controlled area[e]

a. EIS Appendix F includes a primer on potential human health effects from exposure to radionuclides.
b. Annual committed effective dose equivalent, a combination of the dose an individual could absorb during a full year and any subsequent dose over a defined period of time from radionuclides remaining within the individual as a result of the dose absorbed during the year.
c. N/A = not applicable.
d. Represents a person who resides in the accessible environment above the highest concentration of radionuclides in the plume of contamination. The reasonably maximally exposed individual approach is based on providing a sufficient level of protection to this individual so that all other persons, who would be less exposed, would also be protected.
e. The location where projected concentrations would be highest, no closer to the repository than the edge of the controlled area. The controlled area would be 300 square kilometers (120 square miles) maximum surface and subsurface area that extends in the predominant direction of groundwater flow no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude (the present southwest corner of the Nevada Test Site), and no more than 5 kilometers (3 miles) from the repository footprint in any other direction. The controlled area would be the area restricted long term for the repository as identified by passive institutional controls DOE would implement at closure.

National Environmental Policy Act of 1969, as Amended (42 U.S.C. 4321 *et seq.*)

DOE has prepared this EIS in accordance with the provisions of the National Environmental Policy Act as implemented by Council on Environmental Quality regulations (40 CFR Parts 1500 through 1508) and DOE National Environmental Policy Act regulations (10 CFR Part 1021), and in conformance with the NWPA.

Atomic Energy Act of 1954, as Amended (42 U.S.C. 2011 *et seq.*)

The Atomic Energy Act, as amended, provides fundamental jurisdictional authority to DOE and the Nuclear Regulatory Commission over governmental and commercial use of nuclear materials. The Atomic Energy Act ensures proper management, production, possession, and use of radioactive materials. In accordance with the Atomic Energy Act, DOE has established a system of requirements that it has issued as DOE Orders.

The Atomic Energy Act gives the Nuclear Regulatory Commission specific authority to regulate the possession, transfer, storage, and disposal of nuclear materials, as well as aspects of transportation packaging design requirements for radioactive materials, including testing for packaging certification. Commission regulations applicable to the transportation of radioactive materials (10 CFR Parts 71 and 73) require that shipping casks meet specified performance criteria under both normal transport and hypothetical accident conditions.

Under the Atomic Energy Act of 1954, as amended, the Environmental Protection Agency has the authority to develop generally applicable standards for protection of the general environment from radioactive material.

Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 *et seq.*)

The Federal Land Policy and Management Act governs the use of Federal lands administered by the Bureau of Land Management, which is an agency of the U.S. Department of the Interior. Access to and use of public lands administered by the Bureau are primarily governed by the regulations regarding the establishment of rights-of-way (43 CFR Part 2800; see Table 11-1, item 17) and withdrawals of public domain land from public use (43 CFR Part 2300; see Table 11-1, item 4), as described below in this section.

Some implementing alternative branch rail lines, routes for heavy-haul trucks, and intermodal transfer station locations that could be involved in transportation of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would cross or occupy land administered by the Bureau of Land Management and would require right-of-way reservations (see Table 11-1, item 17). DOE has obtained right-of-way reservations from the Bureau of Land Management and a concurrence from the U.S. Air Force for access to the Yucca Mountain vicinity for characterization activities.

To develop a monitored geologic repository at Yucca Mountain, DOE would need to obtain control of Bureau of Land Management, Air Force, and DOE lands in western Nevada. Land withdrawal is the method by which the Federal Government gives exclusive control of land it owns to a particular agency for a particular purpose. Nuclear Regulatory Commission licensing conditions for a repository include a requirement that DOE either own or have permanent control of lands for which it is seeking a repository license, and that lands used for a repository be free and clear of all encumbrances, if significant, such as (1) rights arising under the general mining laws, (2) easements or rights-of-way, and (3) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

The Federal Land Policy and Management Act, by which the Government accomplishes most Federal land withdrawals, contains a detailed procedure for application, review, and study by the Bureau of Land Management, and decisions by the Secretary of the Interior on withdrawal and on the terms and conditions of withdrawal. Withdrawals accomplished through the Federal Land Policy and Management Act remain valid for no more than 20 years and, therefore, do not appear to meet the permanency of control required by the Nuclear Regulatory Commission.

Only Congress has the power to withdraw Federal lands permanently for the exclusive purposes of specific agencies. Through legislative action, Congress can authorize and direct a permanent withdrawal of lands such as those proposed for the Yucca Mountain Repository. In addition, Congress would determine any conditions associated with the land withdrawal. In the absence of specific direction to another Federal agency the Bureau of Land Management would ordinarily administer details of a Congressional withdrawal, following the provisions of 43 CFR Part 2300.

Executive Order 11514, *National Environmental Policy Act, Protection and Enhancement of Environmental Quality*

Executive Order 11514 directs Federal agencies to monitor and control their activities continually to protect and enhance the quality of the environment. The Order also requires the development of procedures both to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs with potential environmental impacts, and to obtain the views of interested parties. DOE has promulgated regulations (10 CFR Part 1021, *National Environmental Policy Act Implementing Procedures*) and has issued a DOE Order (451.1A, *National Environmental Policy Act Compliance Program*) to ensure compliance with this Executive Order.

11.2 Statutes, Regulations, and Orders Regarding Environmental Protection Requirements

11.2.1 AIR QUALITY

Clean Air Act, as amended (42 U.S.C. 7401 *et seq.*)

The Clean Air Act is intended to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population." Section 118 of the Act requires Federal agencies such as DOE, with jurisdiction over any property or facility that might result in the discharge of air pollutants, to comply with "all Federal, state, interstate, and local requirements" related to the control and abatement of air pollution.

The Clean Air Act requires the Environmental Protection Agency to establish National Ambient Air Quality Standards to protect public health, with an adequate margin of safety, from any known or anticipated adverse effects of a regulated pollutant (42 U.S.C. 7409). It also requires the establishment of national standards of performance for new or modified stationary sources of atmospheric pollutants (42 U.S.C. 7411) and the evaluation of specific emission increases to prevent a significant deterioration in air quality (42 U.S.C. 7470). Air emission standards are established at 40 CFR Parts 50 through 99. The Clean Air Act specifically regulates emissions of hazardous air pollutants, including radionuclides, through the National Emission Standards for Hazardous Air Pollutants Program at 40 CFR Parts 61 and 63 (see Table 11-1, items 5 and 7).

Nevada Revised Statutes: Air Emission Controls, Chapter 445B

These statutes and regulations in the Nevada Administrative Code implement State and Federal Clean Air Act provisions, identify the requirements for permits for each air pollution source (unless it is specifically exempted), and identify ongoing monitoring requirements. In accordance with the Clean Air Act, DOE could have to obtain an Operating Permit from the Nevada Division of Environmental Protection for the control of gaseous, liquid, and particulate emissions associated with the construction and operation of a repository at Yucca Mountain (see Table 11-1, item 6). To ensure that its site characterization activities comply with applicable Clean Air Act and State provisions, DOE has obtained an operating permit for surface disturbances and point source emissions.

11.2.2 WATER QUALITY

Safe Drinking Water Act, as amended [42 U.S.C. 300(f) *et seq.*]

The primary objective of the Safe Drinking Water Act is to protect the quality of public water supplies, including any drinking water system at the proposed repository. This law grants the Environmental Protection Agency the authority to protect the quality of public drinking water supplies by establishing national primary drinking water regulations. In accordance with the Safe Drinking Water Act, the

Environmental Protection Agency has delegated authority for enforcement of drinking water standards to the states. Regulations (40 CFR Parts 123, 141, 145, 147, and 149) specify maximum contaminant levels, including those for radioactivity, in public water systems, which are generally defined as systems that serve at least 15 service connections or regularly serve at least 25 year-round residents.

In 1978, the Environmental Protection Agency approved the Nevada program for enforcing drinking water standards. The Nevada Health Division is responsible for enforcement of these standards. The proposed repository would include a drinking water system that obtained water from a source off the repository site, and DOE would operate the system in accordance with Nevada Health Division permitting requirements, if applicable (see Table 11-1, items 9, 10, 11, and 16).

Clean Water Act of 1977 (33 U.S.C. 1251 *et seq.*)

The purpose of the Clean Water Act, which amended the Federal Water Pollution Control Act, is to "restore and maintain the chemical, physical, and biological integrity of the Nation's water." The State of Nevada has been delegated the authority to implement and enforce most programs in the State under the Clean Water Act; exceptions include those addressed by Section 404, which is administered by the U.S. Army Corps of Engineers, as described below in this section.

The Clean Water Act prohibits the "discharge of toxic pollutants in toxic amounts" to navigable waters of the United States. Section 313 of the Act generally requires all departments and agencies of the Federal Government engaged in any activity that might result in a discharge or runoff of pollutants to surface waters to comply with Federal, state, interstate, and local requirements. Under the Clean Water Act, states generally set water quality standards, and the Environmental Protection Agency and states regulate and issue permits for point-source discharges as part of the National Pollutant Discharge Elimination System permitting program. The Environmental Protection Agency regulations for this program are codified at 40 CFR Part 122, and Nevada rules for this program are codified at Nevada Administrative Code Chapter 445A. If the construction or operation of a Yucca Mountain Project facility or associated transportation route in Nevada would result in point-source discharges, DOE could need to obtain a National Pollutant Discharge Elimination System permit from the State of Nevada Division of Environmental Protection (see Table 11-1, item 10).

Sections 401 and 405 of the Water Quality Act of 1987 added Section 402(p) to the Clean Water Act. Section 402(p) requires the Environmental Protection Agency to establish regulations for the Agency or individual states to issue permits for stormwater discharges associated with industrial activity, including construction activities that could disturb 5 or more acres (40 CFR Part 122). Nevada rules for this program are codified at Nevada Administrative Code Chapter 445A. The Agency has promulgated regulations implementing a separate stormwater permit application process.

Section 404 of the Clean Water Act gives the U.S. Army Corps of Engineers permitting authority over activities that discharge dredge or fill material into waters of the United States. DOE could need to obtain a permit from the Corps for activities associated with a repository at Yucca Mountain if those activities would discharge dredge or fill into any such waters. If the construction or modification of rail lines or highways to the repository included dredge or fill activities or other actions that would discharge dredge or fill into waters of the United States, those activities would also require Section 404 permits. DOE has obtained a Section 404 permit for site characterization-related construction activities it might conduct in Coyote Wash or its tributaries or in Fortymile Wash.

Nevada Revised Statutes: Water Controls, Chapter 445A

These statutes classify the waters of the State, establish standards for the quality of all waters in the State, and specify permitting and notification provisions for stormwater discharges and for other discharges to waters of the State in accordance with provisions of the Federal Clean Water Act. These statutes and regulations in the Nevada Administrative Code also (1) set drinking water standards, specifications for certification, and conditions for issuance of variances and exemptions, (2) set standards and requirements for the construction of wells and other water supply systems, (3) establish the different classes of wells and aquifer exemptions, and (4) establish requirements for well operation and monitoring, plugging, and abandonment activities. Regardless of whether these provisions are applicable, DOE has obtained an Underground Injection Control Permit and a Public Water System Permit for site characterization activities at Yucca Mountain. The Underground Injection Control Permit covers tracers, pump tests, and similar activities. The Public Water System Permit establishes the terms for the provision of potable water.

The Department would install and operate the drinking water system planned for the proposed repository in accordance with Nevada Health Division standards, if applicable, and would obtain a Water System Operating Permit from the Nevada Health Division (see Table 11-1, item 9), if needed. DOE could also need to obtain a General Permit for Storm Water Discharge from the Nevada Division of Water Resources to construct and operate a repository at Yucca Mountain (see Table 11-1, item 10). Any point-source discharges to waters of the State that occurred in the course of Yucca Mountain Project activities could require a National Pollutant Discharge Elimination System permit issued under these provisions. DOE has obtained a general discharge permit from the State for effluent discharges to the ground surface during site characterization.

Nevada Revised Statutes: Adjudication of Vested Water Rights; Appropriation of Public Waters, Chapter 533; Underground Water and Wells, Chapter 534

These statutes and accompanying regulations in the Nevada Administrative Code establish permitting procedures for appropriating public waters of the State, including underground waters, for beneficial use.

DOE has obtained temporary permits for the use of underground water from several wells during site characterization.

It is the policy of the United States Government to apply for water in accordance with state laws. In 1997, DOE applied for an appropriation of water to fulfill the purpose of the NWPA, for the proposed repository in accordance with the provisions of Chapters 533 and 534 of the Nevada Revised Statutes. The Nevada State Engineer denied the DOE water appropriation applications, and DOE appealed the denial in court. The denial is being litigated. On October 15, 2001, the United States Court of Appeals for the Ninth Circuit set the matter for trial in the U.S. District Court for the State of Nevada (No. 00-17330, D.C. No. CV-00-268-RLH).

Chapter 534 of the Nevada Revised Code establishes requirements applicable to drilling, construction, and plugging of wells for extraction of underground water.

Executive Order 11988, *Floodplain Management*

This Order directs Federal agencies to establish procedures to ensure that any Federal action undertaken in a floodplain considers the potential effects of flood hazards and floodplain management and avoids floodplain impacts to the extent practicable. For its site characterization activities, DOE conducted a floodplain assessment (see Appendix L) in accordance with this Order (DIRS 103189-DOE 1992, all) and DOE implementing regulations (10 CFR Part 1022).

Compliance With Floodplain/Wetlands Environmental Review Requirements (10 CFR Part 1022)

Federal regulations (10 CFR Part 1022) establish policy and procedures for implementing Executive Order 11988, *Floodplain Management*, and for discharging DOE responsibilities regarding the consideration of floodplain/wetlands factors in DOE planning and decisionmaking. These regulations also establish DOE procedures for identifying proposed actions located in floodplains, providing opportunity for early public review of such proposed actions, preparing floodplain assessments, and issuing statements of findings for actions in a floodplain. The rules apply to all DOE proposed floodplain actions.

If DOE determines that an action it proposes would take place wholly or partly in a floodplain, it is required to prepare a notice of floodplain involvement and a floodplain assessment containing a project description, a discussion of floodplain effects, alternatives, and mitigations. For a proposed floodplain action for which a National Environmental Policy Act document such as an environmental impact statement or an environmental assessment is required, DOE is to include the floodplain assessment in the document. For floodplain actions for which DOE does not have to prepare such a document, the Department is to issue a separate document as the floodplain assessment. After the conclusion of public comment, DOE is to reevaluate the practicability of alternatives and of mitigation measures, considering all substantive comments.

If it finds that no practicable alternative to locating in the floodplain is available, DOE must design or modify its action to minimize potential harm to and within the floodplain. For actions in a floodplain, DOE must publish a statement of findings of three pages or less containing a brief description of the proposed action, a location map, an explanation indicating the reason for locating the action in the floodplain, a list of alternatives considered, a statement indicating whether the action conforms to applicable State or local floodplain protection standards, and a brief description of steps DOE will take to minimize potential harm to or within the floodplain. For floodplain actions that require the preparation of an EIS, the Final EIS can incorporate the statement of findings. Before implementing a proposed floodplain action, DOE must endeavor to allow at least 15 days of public review of the statement of findings.

Appendix L contains a statement of findings on the potential for repository construction and operation to affect floodplains. Appendix L also contains a floodplain/wetlands assessment that examines the effects of proposed repository construction and operation and potential construction of a rail line or intermodal transfer station. The assessment includes discussion of:

1. Floodplains near Yucca Mountain (Fortymile Wash, Busted Butte Wash, Drillhole Wash, and Midway Valley Wash); there are no delineated wetlands at Yucca Mountain.

2. What is known about floodplains and areas that might have wetlands (for example, springs and riparian areas) along potential rail corridors in Nevada and at intermodal transfer station locations associated with heavy-haul truck routes. If DOE selected rail as the mode of spent nuclear fuel and high-level radioactive waste transport in Nevada, it would select one of the rail corridors, and would prepare a more detailed floodplains/wetlands assessment of the selected corridor. If DOE selected heavy-haul truck as the mode of transport for spent nuclear fuel and high-level radioactive waste in Nevada, it would select one of five heavy-haul truck routes and one of three intermodal transfer stations, and would prepare a more detailed floodplain/wetlands assessment of the selected heavy-haul truck route and the associated intermodal transfer station.

11.2.3 HAZARDOUS MATERIALS PACKAGING, TRANSPORTATION, AND STORAGE

Roles of U.S. Department of Transportation and Nuclear Regulatory Commission in Regulating the Transportation of Radioactive Materials

The U.S. Department of Transportation and Nuclear Regulatory Commission share primary responsibility for regulating safe transportation of radioactive materials in the United States. The Department of Transportation has responsibility to develop and implement transportation safety standards for hazardous materials, including radioactive materials. In Title 49 of the Code of Federal Regulations, the Department of Transportation has established standards and requirements for packaging, transporting, and handling radioactive materials for all modes of transportation, including standards for labeling, shipping papers, placarding, loading and unloading, allowable radioactive levels, and limits for contamination of packages and vehicles, among other requirements. The regulations also specify safety requirements for vehicles and transportation operations, training for personnel who perform handling and transportation of hazardous materials, and liability insurance requirements for carriers.

The Nuclear Regulatory Commission regulates the packaging- and transportation-related operations of its licensees, including commercial shippers of radioactive materials. It sets design and performance standards for packaging (shipping casks) that carry materials with higher levels of radioactivity. The Department of Transportation, by agreement with the Nuclear Regulatory Commission, accepts the Commission standards of 10 CFR Part 71 for packaging. The Nuclear Regulatory Commission also establishes safeguards and security regulations to minimize the possibility of theft, diversion, or attack on shipments of radioactive materials (10 CFR Part 73). Title 10 of the Code of Federal Regulations details these requirements. As required by the NWPA (Section 180), carriers would make all shipments to Yucca Mountain in Nuclear Regulatory Commission-certified packages and in accordance with Commission regulations on advance notification of state and local governments. Appendix M contains a detailed discussion of regulatory responsibilities for transportation activities.

Hazardous Materials Transportation Act (49 U.S.C. 1801)

The Hazardous Materials Transportation Act gives the U.S. Department of Transportation authority to regulate the transport of hazardous materials, including radioactive materials such as those that would be transported to the proposed Yucca Mountain Repository from 72 commercial and 5 DOE sites. Department of Transportation regulations (49 CFR Parts 171 through 180) would require the identification of hazardous materials during transportation to a repository at Yucca Mountain, set forth rules for the selection of routes that carriers must use when transporting such materials, and provide guidance to states in designating preferred routes.

Emergency Planning and Community Right-to-Know Act of 1986 (42 U.S.C. 1001 *et seq.*)

Under Subtitle A of the Emergency Planning and Community Right-to-Know Act (also known as "SARA Title III"), Federal facilities, including a repository at Yucca Mountain, must provide information on hazardous and toxic chemicals to state emergency response commissions, local emergency planning committees, and the Environmental Protection Agency. The goal of providing this information is to ensure that emergency plans are sufficient to respond to unplanned releases of hazardous substances. The required information includes inventories of specific chemicals used or stored and descriptions of releases that occur from sites. This law, implemented at 40 CFR Parts 302 through 372, requires agencies to provide material safety data sheet reports, emergency and *hazardous chemical* inventory reports, and toxic chemical release reports to appropriate local, state, and Federal agencies. DOE has been complying with the provisions of the Emergency Planning and Community Right-to-Know Act and with regulations for maintaining and using inventories of chemicals for site characterization activities. If the proposed repository received a license, DOE would continue to comply with such provisions, as applicable, in storing and using chemicals for project activities.

Nevada Revised Statutes: Hazardous Materials, Chapter 459

A Nevada Hazardous Materials Storage Permit could be required to store hazardous materials in quantities greater than those specified in the Uniform Fire Code. To receive such a permit, if sought, DOE would submit an application to the Nevada State Fire Marshal (Nevada Revised Statutes, Chapter 477) that describes its plans for the storage of hazardous materials in excess of specified quantities (see Table 11-1, item 19). If permit renewal was sought each year, DOE would have to submit an annual report to the State Fire Marshal that complied with the reporting requirements of the Federal Emergency Planning and Community-Right-to-Know Act, Sections 302, 311, and 312. Regardless of whether these provisions are applicable, DOE has obtained a permit from the State Fire Marshal for the storage of flammable materials during site characterization activities.

Nuclear Regulatory Commission Radioactive Materials Packaging and Transportation Regulations (10 CFR Parts 71 and 73)

Under 10 CFR Part 71, the Nuclear Regulatory Commission regulates the packaging and transport of spent nuclear fuel for its licensees, which include commercial shippers of radioactive material and the DOE Office of Civilian Radioactive Waste Management. In addition, under an agreement with the U.S. Department of Transportation, the Commission sets the standards for packages containing Type B quantities of radioactive materials, including high-level radioactive waste and spent nuclear fuel. Type B packages are designed and built to retain their radioactive contents in both normal and accident conditions.

The demonstration of compliance with these requirements applies a combination of simple calculational methods, computer modeling techniques, and physical testing to the design features of the package. An applicant presents the results of the analyses and tests to the Nuclear Regulatory Commission in a Safety Analysis Report for Packaging, which the Commission, after review, approves by issuing a Certificate of Compliance. This certificate would be required for the use of a package (cask) to ship spent nuclear fuel or high-level radioactive waste to the repository.

The regulations at 10 CFR Part 73 govern safeguards and physical security during the transit of shipments of spent nuclear fuel. These regulations specify requirements for vehicles, carrier personnel, communications, notification of state governors, escorts, and route planning for such shipments.

Department of Transportation Hazardous Materials Packaging and Transportation Regulations (49 CFR Subchapter C – Hazardous Materials Regulations, Parts 171 Through 180)

The Department of Transportation regulates the shipments of hazardous materials, including spent nuclear fuel and high-level radioactive waste, in interstate and intrastate commerce by land, air, and navigable water. As outlined in a 1979 Memorandum of Understanding with the Nuclear Regulatory Commission (44 *FR* 38690, July 2, 1979), the Department of Transportation specifically regulates carriers of spent nuclear fuel and the conditions of transport, such as routing, handling and storage, and vehicle and driver requirements. It also regulates the labeling, classification, and marking of transportation packages for radioactive materials.

Department of Transportation regulations include requirements for carriers, drivers, vehicles, routing, packaging, labeling, marking, placarding of vehicles, shipping papers, training, and emergency response. The requirements specify the maximum dose rate associated with radioactive material shipments and the maximum allowable levels of radioactive surface contamination on packages and vehicles.

The public highway routing regulations of the Department of Transportation are prescribed in 49 CFR Part 397. The objectives of the regulations are to reduce the impacts of transporting highway route-controlled quantities of radioactive materials to establish consistent and uniform requirements for route selection, and to identify the role of state and local governments in the routing. The requirements at 49 CFR 173.403(l) contain a complete definition of *Highway Route-Controlled Quantities of Radioactive Material*.

Shipping casks transported by legal-weight trucks typically would contain about 300,000 curies of radionuclides, and rail casks typically would contain larger quantities. These regulations attempt to reduce potential hazards by requiring the use of routes that avoid populous areas and minimize travel times. At present, the Department of Transportation does not regulate the routing of rail shipments of radioactive materials. Department of Transportation regulations also include requirements to protect the health and safety of transportation workers.

11.2.4 CONTROL OF POLLUTION

Pollution Prevention Act of 1990 (42 U.S.C. 13101 *et seq.*)
The Pollution Prevention Act of 1990 establishes a national policy for waste management and pollution control that focuses first on source reduction, then on environmentally safe recycling, treatment, and disposal. DOE requires each of its sites to establish specific goals to reduce the generation of waste. If the Department built and operated a repository at the Yucca Mountain site, it would implement an appropriate pollution prevention plan. DOE has implemented a pollution prevention plan for site characterization activities. DOE would update this plan to include construction, operation and monitoring, and closure activities if the repository received a license.

Comprehensive Environmental Response, Compensation, and Liability Act, as amended (42 U.S.C. 9601 *et seq.*)
The Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments and Reauthorization Act, authorizes the Environmental Protection Agency to require responsible site owners, operators, arrangers, and transporters to clean up releases of hazardous substances, including certain radioactive substances. Under this Act, the Environmental Protection Agency would have the authority to regulate hazardous substances, including certain radioactive materials, at the Yucca Mountain Repository in the event of a release or a "substantial threat of a release" of those materials from the repository. Releases greater than reportable quantities would be reported to the National Response Center.

Standards for Protection Against Radiation (10 CFR Part 20)
The purpose of 10 CFR Part 20 is to provide standards and procedures for protection against radiation. Provisions of 10 CFR Part 20 address repository occupational dose limits, public dose limits, survey and monitoring procedures, exposure control in restricted areas, respiratory protection and controls, precautionary procedures, and related topics.

Low-Level Radioactive Waste Policy Amendments Act of 1985 (P.L. 99-240)
Under the Low-Level Radioactive Waste Policy Amendments Act of 1985 (P.L. 99-240), DOE is responsible for disposal of any low-level waste generated by operations at the proposed Yucca Mountain Repository. Such waste would be considered DOE-owned and -generated waste.

On February 25, 2000, DOE issued a Record of Decision (65 *FR* 10061) to establish regional low-level waste disposal at the Hanford Site and Nevada Test Site that would be available to all DOE sites. DOE would ensure that Yucca Mountain is an approved generator in accordance with the requirements of Nevada Test Site waste acceptance criteria prior to disposal of any low-level radioactive waste at the Test Site generated from Yucca Mountain Repository operations.

Resource Conservation and Recovery Act, as amended (42 U.S.C. 6901 *et seq.*)
The treatment, storage, and disposal of hazardous and nonhazardous waste is regulated in accordance with the provisions of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments of 1984, and applicable state laws.

Environmental Protection Agency regulations implementing the hazardous waste portions of the Resource Conservation and Recovery Act define hazardous wastes and specify requirements for their transportation, handling, treatment, storage, and disposal (40 CFR Parts 260 through 272). In addition, under current Civilian Radioactive Waste system requirements, DOE could not accept hazardous waste for disposal at Yucca Mountain. Before shipping to Yucca Mountain, DOE would treat materials that contained hazardous components to eliminate the hazardous waste characteristics. Before shipping materials containing hazardous components listed under Subpart D of Part 261 or applicable state requirements, DOE would process any necessary delisting petitions with the appropriate regulatory authorities. If the activities at Yucca Mountain generated hazardous or mixed waste, the Department would not dispose of such waste on the site and would not treat such waste in a manner that required Resource Conservation and Recovery Act permitting, and would not store such waste on the site for more than 90 days. DOE does not expect to need a Resource Conservation and Recovery Act permit for its activities at the proposed repository.

Noise Control Act of 1972, as amended (42 U.S.C. 4901 *et seq.*)

Section 4 of the Noise Control Act directs Federal agencies to carry out programs in their jurisdictions "to the fullest extent within their authority" and in a manner that furthers a national policy of promoting an environment free from noise that jeopardizes health and welfare. This law provides requirements related to noise that would be generated by construction, operation, or closure activities associated with the Proposed Action at Yucca Mountain.

Nevada Revised Statutes: Sanitation, Chapter 444

These statutes and regulations in the Nevada Administrative Code establish the standards, permits, and requirements for septic tanks and other sewage disposal systems for single-family dwellings, communities, and commercial buildings. The construction and operation of a sanitary sewage collection system at Yucca Mountain could require the State of Nevada to approve DOE designs and to issue a permit. In connection with site characterization activities, DOE operates a septic system that the State has permitted under these provisions.

These statutes and regulations also set forth the definitions, methods of disposal, special requirements for solid waste collection and transportation standards, and classification of landfills. Onsite disposal of solid waste from a repository at Yucca Mountain could require that DOE obtain an appropriate permit for these activities.

In compliance with the Resource Conservation and Recovery Act, the Environmental Protection Agency has authorized the State of Nevada to regulate the management and disposal of solid, hazardous, and mixed wastes in the State. The Nevada Division of Environmental Protection or an equivalent solid waste management authority would regulate the onsite disposal of nonhazardous solid wastes generated by activities associated with the proposed repository. DOE would manage such waste in accordance with applicable laws and regulations.

Nevada Administrative Code Chapter 444 contains regulations that provide for fees, variances, and permits, and has adopted Environmental Protection Agency regulations (40 CFR Parts 2, 124, and 260 through 270) as part of the code. The regulations could affect any hazardous or mixed waste generated, treated, or stored onsite by activities associated with a proposed repository at Yucca Mountain. DOE would ship any generated hazardous or mixed wastes off the site within 90 days for treatment, storage, and disposal.

Executive Order 12088, *Federal Compliance with Pollution Control Standards*

Executive Order 12088, as amended by Executive Order 12580, *Superfund Implementation Control Standards*, generally directs Federal agencies to comply with applicable administrative and procedural pollution control standards established by, but not limited to, the Clean Air Act, the Noise Control Act, the Clean Water Act, the Safe Drinking Water Act, the Toxic Substances Control Act, and the Resource Conservation and Recovery Act. Compliance with these orders, as applicable, would be required for a range of DOE activities associated with a proposed repository at Yucca Mountain.

Executive Order 12856, *Right to Know Laws and Pollution Prevention Requirements*

This Order directs Federal agencies to reduce and report toxic chemicals entering any waste stream; improve emergency planning, response, and accident notification; and encourage the use of clean technologies and testing of innovative prevention technologies. In addition, the Order states that Federal agencies are persons for purposes of the Emergency Planning and Community Right-to-Know Act (SARA Title III), which requires agencies to meet the requirements of the Act. Compliance with these orders, as applicable, would be required for a range of DOE activities associated with a proposed repository at Yucca Mountain.

11.2.5 CULTURAL RESOURCES

National Historic Preservation Act, as amended (16 U.S.C. 470 *et seq.*)

The National Historic Preservation Act provides for the placement of sites with significant national historic value on the *National Register of Historic Places*. It requires no permits or certifications. DOE would evaluate activities associated with a repository at Yucca Mountain to determine if they would affect historic resources. If required after this evaluation, the Department would consult with the Advisory Council on Historic Preservation and the Nevada State Historic Preservation Officer. Such consultations generally result in the development of an agreement that includes stipulations to be followed to minimize or mitigate potential adverse impacts to a historic resource (see Table 11-1, item 12).

DOE has entered into a programmatic agreement with the Advisory Council on Historic Preservation for implementation of the National Historic Preservation Act for site characterization activities. This agreement requires DOE to consult and interact with Native Americans during site characterization. In compliance with the agreement provisions, Native American representatives from the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone Tribes have reviewed Yucca Mountain activities on the site twice each year. These reviews have been followed by discussions between Native American representatives and DOE personnel, submittal of comments by the Native American representatives, and responses to the comments by DOE.

Archaeological Resources Protection Act, as amended (16 U.S.C. 470aa *et seq.*)

The Archaeological Resources Protection Act requires a permit for excavation or removal of archaeological resources from publicly held or Native American lands (see Table 11-1, item 14). Excavations must further archaeological knowledge in the public interest, and the resources removed are to remain the property of the United States. If a resource is found on land owned by a Native American tribe, the tribe must give its consent before a permit is issued, and the permit must contain terms or conditions requested by the tribe. Requirements of the Archaeological Resources Protection Act would apply to any Yucca Mountain Project excavation activities that resulted in identification of archaeological resources.

American Indian Religious Freedom Act of 1978 (42 U.S.C. 1996)

The American Indian Religious Freedom Act reaffirms Native American religious freedom under the First Amendment and establishes policy to protect and preserve the inherent and constitutional right of Native Americans to believe, express, and exercise their traditional religions. This law ensures the protection of sacred locations and access of Native Americans to those sacred locations and traditional resources that are integral to the practice of their religions. Further, it establishes requirements that would apply to Native American sacred locations, traditional resources, or traditional religious practices potentially affected by the construction and operation of a repository at Yucca Mountain.

Native American Graves Protection and Repatriation Act of 1990 (25 U.S.C. 3001)

The Native American Graves Protection and Repatriation Act directs the Secretary of the Interior to guide the repatriation of Federal archaeological collections and collections that are culturally affiliated with Native American tribes and held by museums that receive Federal funding. Major actions to be taken under this law include (1) the establishment of a review committee with monitoring and policymaking responsibilities, (2) the development of regulations for repatriation, including procedures for identifying lineal descent or cultural affiliation needed for claims, (3) the oversight of museum programs designed to meet the inventory requirements and deadlines of this law, and (4) the development of procedures to handle unexpected discoveries of graves or grave goods during activities on Federal or tribal land. The provisions of the Act would be invoked if any excavations associated with a repository at Yucca Mountain led to unexpected discoveries of Native American graves or grave artifacts. DOE and the Southern Paiute, Western Shoshone, and Owens Valley Paiute and Shoshone Tribes have entered an agreement to address the potential applicability of the Native American Graves Protection and Repatriation Act to artifacts collected during site characterization activities at Yucca Mountain.

Antiquities Act (16 U.S.C. 431 *et seq.*)

The Antiquities Act protects historic and prehistoric ruins, monuments, and objects of antiquity (including paleontological resources) on lands owned or controlled by the Federal Government. If historic or prehistoric ruins or objects were found during the construction or operation of facilities associated with a repository at Yucca Mountain, DOE would have to determine if adverse effects to these ruins or objects would occur. If adverse effects would occur, the Secretary of the Interior would have to grant permission to proceed with the activity (36 CFR Part 296 and 43 CFR Parts 3 and 7) (see Table 11-1, item 13).

Executive Order 13007, *Indian Sacred Sites*

This Order directs Federal agencies, to the extent permitted by law and not inconsistent with agency missions, to avoid adverse effects to sacred sites and to provide access to those sites to Native Americans for religious practices. The Order directs agencies to plan projects to provide protection of and access to sacred sites to the extent compatible with the project.

Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*

This Order directs Federal agencies to establish regular and meaningful consultation and collaboration with tribal governments in the development of Federal policies that have tribal implications, to strengthen United States government-to-government relationships with Indian tribes, and to reduce the imposition of unfunded mandates on tribal governments.

11.2.6 ENVIRONMENTAL JUSTICE

Executive Order 12898, *Environmental Justice*

This Order directs Federal agencies, to the extent practicable, to make the achievement of environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority and low-income populations in the United States and its territories and possessions. The order provides that the Federal agency responsibilities it establishes are to apply equally to Native American programs.

11.2.7 ECOLOGY AND HABITAT

Endangered Species Act, as amended (16 U.S.C. 1531 *et seq.*)

The Endangered Species Act provides a program for the conservation of threatened and endangered species and the ecosystems on which those species rely. If a proposed action could affect threatened or endangered species or their habitat, the Federal agency must assess the potential impacts and develop measures to minimize those impacts. The agency then must consult formally with the Fish and Wildlife Service (part of the U.S. Department of the Interior) and the National Marine Fisheries Service (part of the Department of Commerce), as required under Section 7 of the Act. The outcome of this consultation would be a biological opinion by the Fish and Wildlife Service or the National Marine Fisheries Service that stated whether the proposed action would jeopardize the continued existence of the species under consideration. If there is a non-jeopardy opinion, but some individuals are killed incidentally as a result of the proposed action, the Services can determine that such losses are not prohibited as long as measures outlined by the Services are followed. Regulations implementing the Endangered Species Act are codified at 50 CFR Parts 15 and 402.

There are no known endangered species on the Yucca Mountain site. The desert tortoise is the only threatened species found on the site. The Fish and Wildlife Service previously issued a biological opinion stating that site characterization activities at Yucca Mountain would not jeopardize the continued existence of the desert tortoise (DIRS 104618-Buchanan 1997, p. 16).

The U.S. Fish and Wildlife Service has issued a Biological Opinion (50 CFR 402.6; see Table 11-1, item 18) establishing reasonable and prudent meaures and terms and conditions to ensure that constructing, operating and monitoring, and eventually closing a repository at Yucca Mountain would not jeopardize the continued existence of the desert tortoise (see Appendix O). If the repository was approved, DOE would comply with all provisions of the Biological Opinion, including the reasonable and prudent measures and their implementing terms and conditions. DOE would fulfill the requirements of the Endangered Species Act, as appropriate, with regard to transportation impacts before making a final determination on a transportation route.

Fish and Wildlife Coordination Act, as amended (16 U.S.C. 661, 48 Stat. 401)

The Fish and Wildlife Coordination Act promotes more effectual planning and cooperation between Federal, state, public, and private agencies for the conservation and rehabilitation of the Nation's fish and wildlife and authorizes the Department of the Interior to provide assistance.

Migratory Bird Treaty Act, as amended (16 U.S.C. 703 *et seq.*)

The purpose of the Migratory Bird Treaty Act is to protect birds that have common migration patterns between the United States and Canada, Mexico, Japan, and Russia. It regulates the take and harvest of migratory birds. The Fish and Wildlife Service will review this EIS to determine whether the activities analyzed would comply with the requirements of the Migratory Bird Treaty Act. Studies indicate that no requirements of this Act are applicable to the Yucca Mountain Project.

Bald and Golden Eagle Protection Act, as amended (16 U.S.C. 668-668d)

The Bald and Golden Eagle Protection Act makes it unlawful to take, pursue, molest, or disturb bald (American) and golden eagles, their nests, or their eggs anywhere in the United States (Section 668, 668c). The Department of the Interior regulates activities that might adversely affect bald and golden eagles. The Fish and Wildlife Service will review this EIS to determine whether the activities analyzed in this EIS would comply with the Bald and Golden Eagle Protection Act. DOE has established a program to ensure compliance with this law during site characterization activities.

National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd)

The National Wildlife Refuge System Administration Act provides guidelines for the administration and management of lands in the system, including "wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas." If use of lands for transportation corridors and facilities such as a rail line or intermodal transfer station associated with a repository at Yucca Mountain could affect lands in the system, DOE would consult with the Fish and Wildlife Service. Regulations implementing the Act are codified at 50 CFR Parts 25 and 27 through 29. The Fish and Wildlife Service will review this EIS to determine if the Proposed Action would comply with the Act. It is DOE policy to place transportation corridors and facilities to avoid existing wildlife refuges.

Nevada Revised Statutes: Protection and Preservation of Timbered Lands, Trees, and Flora, Chapter 527

These provisions broadly protect the indigenous flora of the State of Nevada. If the State determines that a species or subspecies of native flora is threatened with extinction, that species or subspecies is to be placed on the State list of fully protected species. In general, no member of the species or subspecies may be taken or destroyed unless an authorized State official issues a special permit. Activities associated with a repository at Yucca Mountain arguably could affect such species and could require special permits.

Nevada Revised Statutes: Hunting, Fishing, and Trapping; Miscellaneous Protective Measures, Chapter 503; Nevada Administrative Code, Chapter 503: Sections 010-104, General Provisions

These provisions specify procedures for the classification and protection of wildlife. If the State determines that an animal species is threatened with extinction, the species is to be placed on the State list of fully protected species. In general, no member of the species may be taken or destroyed unless the Nevada Division of Wildlife issues a special permit. Activities associated with a repository at Yucca Mountain arguably could affect such species and could require special permits. Regardless of whether these provisions are applicable, DOE has obtained a permit for site characterization activities from the State of Nevada.

Executive Order 11990, *Protection of Wetlands*

This order directs Federal agencies to avoid new construction in wetlands unless there is no practicable alternative and unless the proposed action includes all practicable measures to minimize harm to wetlands that might result from such use. DOE requirements for compliance with wetlands activity review procedures are codified at 10 CFR Part 1022.

Executive Order 13112, *Invasive Species*

This order directs Federal agencies to act to prevent the introduction of or to monitor and control invasive (non-native) species, to provide for restoration of native species, to conduct research, to promote educational activities, and to exercise care in taking actions that could promote the introduction or spread of invasive species. If a repository were constructed at Yucca Mountain, DOE would comply with provisions of this Executive Order as part of construction, operation and monitoring, and closure activities.

Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*

This Order requires Federal agencies to avoid or minimize the negative impacts of their actions on migratory birds, and to take active steps to protect birds and their habitats. The Order directs each Federal agency taking actions having or likely to have a negative impact on migratory bird populations to work with the U.S. Fish and Wildlife Service to develop an agreement to conserve those birds. The Order directs agencies to avoid or minimize impacts to migratory bird populations, take reasonable steps that include restoring and enhancing habitat, prevent or abate pollution affecting birds, and incorporate migratory bird conservation into agency planning processes whenever possible. The Order also requires environmental analyses of Federal actions to evaluate effects of those actions on migratory birds, to control the spread and establishment in the wild of exotic animals and plants that could harm migratory birds and their habitats, and either to provide advance notice of actions that could result in the take of migratory birds or to report annually to the U.S. Fish and Wildlife Service on the numbers of each species taken during the conduct of agency actions. If a repository was constructed at Yucca Mountain, DOE would comply with provisions of this Executive Order as part of construction, operation and monitoring, and closure activities.

11.2.8 USE OF LAND AND WATER BODIES

Coastal Zone Management Act (16 U.S.C. 1451 *et seq.*)

The purpose of the Coastal Zone Management Act is to preserve, protect, develop, restore, and enhance the resources of the Nation's coastal zone. Resources include wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat. This law provides for (1) management to minimize the loss of life and property caused by improper development and by the destruction of natural protective features such as beaches, dunes, wetlands, and barrier islands, and (2) improvement, safeguarding, and restoration of the quality of coastal waters, and for protection of existing uses of those waters. The Coastal Zone Management Act requires priority consideration to coastal-dependent uses and orderly processes for siting major facilities related to national defense, energy, fisheries development, recreation, ports and transportation, and the location of new commercial and industrial developments in or adjacent to areas where such development already exists.

The operation of a repository at Yucca Mountain could require the use of barges for transportation of spent nuclear fuel along portions of routes from some storage facilities. In addition, rail corridors, roads, and bridges from some storage facilities could require repair or enhancement before they could support shipment of spent nuclear fuel. DOE would ensure that its activities are consistent with state-specific coastal zone management plans promulgated in accordance with this Act, if applicable. The regulations promulgated under the Act are codified at 15 CFR Part 930.

Rivers and Harbors Act (33 U.S.C. 401 *et seq.*)

The transportation of spent nuclear fuel and high-level radioactive waste could require the construction or modification of road or rail bridges that span navigable waters. The Rivers and Harbors Act prevents the alteration or modification of the course, location, condition, or capacity of any channel of any navigable water of the United States without a permit from the U.S. Army Corps of Engineers. If DOE assumed responsibility for such construction or modifications, it would need to obtain a permit from the U.S. Army Corps of Engineers. Regulations implementing this Act are codified at 33 CFR Part 323.

National Forest Organic Administrative Act (16 U.S.C. 521)

The National Forest Organic Administrative Act establishes the functions and responsibilities of the Forest Service, an agency of the U.S. Department of Agriculture. The Forest Service would be requested to approve the construction of rail lines and roads in Nevada that would be associated with the operation of a repository at Yucca Mountain and that could cross land administered by the Service (16 U.S.C. 1600, 1611 to 1614).

National Forest Management Act of 1976

The National Forest Management Act establishes decision planning and management practices for forests. This law could affect any proposed construction of rail lines or roads associated with the construction or operation of a repository at Yucca Mountain that could cross National Forest lands.

Materials Act of 1947 (30 U.S.C. 601-603)

The Materials Act authorizes land management agencies, such as the Bureau of Land Management and the Forest Service, to make common varieties of sand, stone, and gravel from public lands available to Federal and state agencies under a Free Use Permit (see Table 11-1, item 15). Regulations implementing the Materials Act are codified at 43 CFR Part 3620. DOE has received three free use permits from the Bureau of Land Management to obtain gravel for site characterization activities in a manner compliant with the Materials Act.

Taylor Grazing Act (43 U.S.C. 315-316)

The Taylor Grazing Act establishes the processes by which the Bureau of Land Management grants and administers grazing rights. If a decision is made to construct and operate a repository, a new rail line, or a new road on a Bureau of Land Management grazing allotment, DOE would have to acquire a right-of-way grant across the allotment or a withdrawal of the allotment. Regulations implementing the Taylor Grazing Act are codified at 43 CFR Part 4100.

Farmland Protection Policy Act (7 U.S.C. 4201 *et seq.*)

The Farmland Protection Policy Act seeks to minimize the extent to which Federal programs contribute to the unnecessary and irreversible conversion of farmlands to nonagricultural uses. Compliance with this law requires concurrence from the Natural Resources Conservation Service of the U.S. Department of Agriculture that proposed activities would not affect farmlands. DOE has completed a consultation with the Natural Resources Conservation Service that determined that a repository at Yucca Mountain would not affect prime or unique farmlands. This EIS assesses the potential construction of a rail line, new roads, or an intermodal transfer station in Nevada to determine if that construction could affect such lands. Regulations implementing the Farmland Protection Policy Act are codified at 7 CFR Part 658.

11.3 Department of Energy Orders

Under the authority of the Atomic Energy Act, DOE is responsible for establishing a comprehensive health, safety, and environmental program for its activities and facilities. The Department has established a framework for managing its facilities through the promulgation of regulations and the issuance of DOE Orders. In general, DOE Orders set forth policies, programs, and procedures for implementing policies. Many DOE Orders contain specific requirements in the areas of radiation protection, nuclear safety and safeguards, and security of nuclear material. Table 11-3 lists DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program.

The Nuclear Regulatory Commission is authorized to license the proposed Yucca Mountain repository. Some DOE Orders overlap or duplicate Nuclear Regulatory Commission repository licensing regulations in whole or in part. Recognizing this, the Department issued DOE HQ Order 250.1, *Civilian Radioactive Waste Management Facilities – Exemption from Departmental Directives.* This Order exempts geologic repository design, construction, operation, and decommissioning from compliance with the provisions of DOE Orders that overlap or duplicate Commission requirements related to radiation protection, nuclear safety (including quality assurance), and safeguard and security of nuclear material. The exemption would apply only to portions of a repository project for which DOE sought a Nuclear Regulatory Commission license. DOE Orders would continue to establish requirements for other activities associated with a repository that fall outside the scope of this exemption, for example in the area of computer security (Order 1360.28).

Through DOE Order 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees,* the Department has prescribed the Occupational Safety and Health Act standards that contractors are to meet in their work at government-owned, contractor-operated facilities.

A monitored geologic repository at Yucca Mountain would be a nonreactor nuclear facility. DOE Orders 5480.21, *Unreviewed Safety Questions*, 5480.22, *Technical Safety Requirements*, and 5480.23, *Nuclear Safety Analysis Reports,* ordinarily apply to nonreactor nuclear facilities. Because DOE Order 250.1 gives precedence to Nuclear Regulatory Commission rules, DOE Orders 5480.21, 5480.22, and 5480.23, for example, probably would not apply to the repository.

11.4 Potentially Applicable Federal Regulations

Sections 11.2.1 through 11.2.8 and Section 11.3 identify major laws, regulations, and DOE Orders potentially applicable to the construction, operation and monitoring, and closure of a monitored geologic repository. Table 11-4 lists other potentially applicable regulations and orders.

Table 11-3. DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program (page 1 of 2).

Order	Subject	Description
151.1	Comprehensive Emergency Management System	Establishes requirements for emergency planning, preparedness, response, recovery, and readiness assurance activities and describes the approach for effectively integrating these activities under a comprehensive, all-emergency concept.
231.1	Environment, Safety and Health Reporting	Establishes the requirements and procedures for reporting information with environmental protection, safety, or health protection significance for DOE operations.
232.1	Occurrence Reporting and Processing of Operations Information	Establishes the requirements for reporting and processing occurrences related to safety, health, security, property, operations, and the environment, up to and including emergencies.
250.1	Civilian Radioactive Waste Management Facilities – Exemption from Departmental Directives	Establishes the relationship between DOE directives and Nuclear Regulatory Commission regulations for the Yucca Mountain Project.
420.1A	Facility Safety	Establishes facility safety requirements related to nuclear safety design, criticality safety, fire protection, and natural phenomena hazards mitigation.
425.1	Facility Startup and Restart	Establishes procedures to be followed when a facility is taken from a nonoperational to an operational state.
430.1	Life Cycle Asset Management	Establishes procedures to be followed in all phases of the management of DOE facilities.
435.1	Radioactive Waste Management	Establishes policies and guidelines by which DOE manages radioactive waste, waste byproducts, and radioactively contaminated surplus facilities.
440.1A	Worker Protection Management for DOE Federal and Contractor Employees	Establishes a comprehensive worker protection program that ensures that DOE and its contractor employees have an effective worker protection program that will reduce or prevent injuries, illnesses, and accidental losses by providing DOE, Federal, and contractor workers with a safe and healthful workplace.
451.1B	National Environmental Policy Act Compliance Program	Establishes DOE internal requirements and responsibilities for implementing the National Environmental Policy Act of 1969, as amended, the Council on Environmental Quality regulations implementing the procedural provisions of the Act (40 CFR Part 1500 *et seq.*), and the DOE procedures that implement it (10 CFR Part 1021).
460.1A	Packaging and Transportation Safety	Establishes requirements and assigns responsibilities for the safe transport of hazardous materials, hazardous substances, hazardous wastes, and radioactive materials.
462.1	Departmental Materials Transportation and Packaging Management	Establishes supplemental policies and requirements for materials transportation and packaging operations.
1300.2A	Department of Energy Technical Standards Program	Establishes policy, assigns responsibility, and provides requirements for development and application of technical standards in DOE facilities, programs, and projects; provides for participation in non-Government standards bodies and for establishment of a DOE Technical Standards Program; and assigns responsibility for the management of the program.

Table 11-3. DOE Orders potentially relevant to the Civilian Radioactive Waste Management Program (page 2 of 2).

Order	Subject	Description
1360.2B	Unclassified Computer Security Program	Establishes requirements, policies, responsibilities, and procedures for developing, implementing, and sustaining a DOE unclassified computer security program.
3790.1B	Federal Employee Occupational Safety and Health Program	Establishes requirements and procedures to ensure that occupational safety and health standards prescribed pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, and the DOE Organization Act of 1977 provide occupational safety and health protection for DOE contractor employees in Government-owned contractor-operated facilities.
5400.1	General Environmental Protection Program	Establishes environmental protection program requirements, authorities, and responsibilities for DOE operations to ensure compliance with applicable Federal, state, and local environmental protection laws and regulations and with internal DOE policies.
5400.5	Radiation Protection of the Public and the Environment	Establishes standards and requirements for operation of DOE and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.
5480.19	Conduct of Operations Requirements for DOE Facilities	Provides requirements and guidelines for DOE elements to use in developing directives, plans, and procedures related to the conduct of operations at DOE facilities.
5484.1	Environmental Protection, Safety, and Health Protection Information Reporting Requirements	Establishes the requirements and procedures for the investigation of occurrences having environmental protection, safety, or health protection significance, and for efficient environmental monitoring of DOE operations.
5610.14	Transportation Safeguards System Program Operations	Establishes DOE policies for and implementation of the management and operation of the Transportation Safeguards System program.
5632.1C	Protection and Control of Safeguards and Security Interests	Establishes policy, responsibilities, and authorities for the protection and control of safeguards and security interests (for example, special nuclear material, vital equipment, classified matter, property, facilities, and unclassified irradiated reactor fuel in transit).
5633.3B	Control and Accountability of Nuclear Materials	Prescribes the minimum DOE requirements and procedures for control and accountability of nuclear materials at DOE-owned and -leased facilities and DOE-owned nuclear materials at facilities that are exempt from licensing by the Nuclear Regulatory Commission. Would apply to materials destined for a repository before the materials reached the repository.

Table 11-4. Other potentially applicable Federal regulations, orders, standards, and memoranda (page 1 of 3).

Document Number	Title[a]
Code of Federal Regulations	
10 CFR Part 2	Rules of Practice for Domestic Licensing Proceedings and Issuance of Orders
10 CFR Part 19	Notices, Instructions and Reports to Workers: Inspection and Investigations
10 CFR Part 40	Domestic Licensing of Source Material
10 CFR Part 51	Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions
10 CFR Part 75	Safeguards on Nuclear Material-Implementation of US/IAEA Agreement
10 CFR Part 100	Reactor Site Criteria
10 CFR Part 707	Workplace Substance Abuse Programs at DOE Sites
10 CFR Part 830	Nuclear Safety Management
10 CFR Part 835	Occupational Radiation Protection
10 CFR Part 1021	National Environmental Policy Act Implementing Procedures
10 CFR Part 1022	Compliance with Floodplain/Wetlands Environmental Review Requirements
29 CFR Part 1926	Safety and Health Regulations for Construction
29 CFR Part 1960	Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters
30 CFR Part 57	Safety and Health Standards, Underground Metal and Nonmetal Mines
33 CFR Part 323	Permits for Discharges of Dredged or Fill Material into Waters of the United States
33 CFR Chapter I	Coast Guard Department of Transportation (Parts 1-199)
36 CFR Part 296	Permits to Proceed (Objects of Antiquity)
36 CFR Part 800	Protection of Historic and Cultural Properties
40 CFR Part 50	National Primary and Secondary Ambient Air Quality Standards
40 CFR Part 60	Standards of Performance for New Stationary Sources
40 CFR Part 61	National Emission Standards for Hazardous Air Pollutants
40 CFR Part 63	National Emission Standards for Hazardous Air Pollutants for Source Categories
40 CFR Part 122	EPA Administered Permit Programs: The National Pollutant Discharge Elimination System
40 CFR Part 125	Criteria and Standards for the National Pollutant Discharge Elimination System
40 CFR Part 133	Secondary Treatment Regulation
40 CFR Part 136	Guidelines Establishing Test Procedures for the Analysis of Pollutants
40 CFR Part 141	National Primary Drinking Water Regulations
40 CFR Part 142	National Primary Drinking Water Regulations Implementation
40 CFR Part 143	National Secondary Drinking Water Regulations
40 CFR Part 246	Source Separation for Materials Recovery Guidelines
40 CFR Part 257	Criteria for Classification of Solid Waste Disposal Facilities and Practices
40 CFR Part 260	Hazardous Waste Management System: General
40 CFR Part 261	Identification and Listing of Hazardous Waste
40 CFR Part 262	Standards Applicable to Generators of Hazardous Waste
40 CFR Part 263	Standards Applicable to Transporters of Hazardous Waste
40 CFR Part 264	Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
40 CFR Part 265	Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities
40 CFR Part 268	Land Disposal Restrictions
40 CFR Part 280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks
40 CFR Part 503	Standards for the Use or Disposal of Sewage Sludge
40 CFR Part 747	Metalworking Fluids
40 CFR Part 761	Polychlorinated Biphenyls Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions
40 CFR Parts 1500 to 1508	Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act

Table 11-4. Other potentially applicable Federal regulations, orders, standards, and memoranda (page 2 of 3).

Document Number	Title[a]
Code of Federal Regulations (continued)	
41 CFR Part 101	Federal Property Management Regulations
43 CFR Parts 3 and 7	Preservation of Antiquities, Protection of Archaeological Resources
43 CFR Part 2300	Land Withdrawal
43 CFR Part 3620	Free Use Permit
43 CFR Part 4100	Grazing Administration, Exclusive of Alaska
49 CFR Part 40	Procedures for Transportation Workplace Drug Testing Programs
49 CFR Part 171	General Information, Regulations and Definitions
49 CFR Part 172	Hazardous Materials Table, Special Provisions, Hazardous Materials Communications Requirements and Emergency Response Information Requirements
49 CFR Part 173	Shippers – General Requirements for Shipments and Packagings
49 CFR Part 174	Carriage by Rail
49 CFR Part 176	Carriage by Vessel
49 CFR Part 177	Carriage by Public Highway
49 CFR Part 178	Shipping Container Specifications
49 CFR Part 180	Continuing Qualification and Maintenance of Packagings
49 CFR Part 392	Driving of Motor Vehicles
49 CFR Part 393	Parts and Accessories Necessary for Safe Operation
49 CFR Part 395	Hours of Service for Drivers
50 CFR Part 17	Endangered and Threatened Wildlife and Plants
50 CFR Part 400	Endangered Species Act
50 CFR Part 402	Interagency Cooperation – Endangered Species Act of 1973, as Amended
Executive Orders	
Executive Order 11514	National Environmental Policy Act, Protection and Enhancement of Environmental Quality
Executive Order 11988	Floodplain Management
Executive Order 11990	Protection of Wetlands
Executive Order 12856	Right to Know Laws and Pollution Prevention Requirements
Executive Order 12898	Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
Executive Order 13007	Indian Sacred Sites
Executive Order 13084	Consultation and Coordination with Indian Tribal Governments
Executive Order 13132	Federalism
Other documents, orders and directives	
AAR Rule 91	1993 Field Manual of Association of American Railroads Interchange Rules (AAR Interchange Rule 91, Weight Limitations)
BLM Manual, Sec. 9113	Bureau of Land Management Manual, Road Standards
DOE Order 430.1	Life Cycle Asset Management
DOE Order 3790.1	Federal Employees Occupational Safety and Health Program
DOE Order 5480.4	Environmental Protection, Safety, and Health Protection Standards
DOE Order 5632.1	Protection Program Operation
DOE/EA-0179	Environmental Assessment Waste Form Selection for Savannah River HLW
DOE/EH-0256T	DOE Radiological Control Manual
DOE/RW-0184	Characteristics of Potential Repository Wastes, Volumes 1-4
DOE/RW-0194P	Records Management Policies and Requirements
DOE/RW-0328P	Acceptance Priority Ranking
DOE/RW-0333P	OCRWM Quality Assurance Requirements and Description
DOE/RW-0457	1995 Acceptance Priority Ranking and Annual Capacity Report
DOE-STD-1020	Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
DOE-STD-1021	Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems and Components
DOE-STD-1022	Natural Phenomena Hazards Site Characterization Criteria

Table 11-4. Other potentially applicable Federal regulations, orders, standards, and memoranda (page 3 of 3).

Document Number	Title[a]
Other documents, orders and directives (continued)	
DOE-STD-1023	Natural Phenomena Hazards Assessment Criteria (Draft)
DOE-STD-1024	Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites
DOE-STD-1062	Ergonomic and Human Factors Design Criteria[b]
Fed-STD-795	Uniform Federal Accessibility Standards
GSA-FSS-W-A-450/1-17	General Service Administration Interim Federal Specification
MOA DP/RW	Policy for Shipping Defense High-Level Waste (DHLW) to a Civilian Radioactive Waste Repository
MOA RW/NS	Nuclear Safety Requirement
MOU DOE/DOL	Mining Safety
NRC RG 1.13	Spent Fuel Storage Facility Design Basis
NRC RG 1.76	Design Basis Tornado for Nuclear Power Plants
NRC RG 8.8	Information Relevant to Ensuring That Occupational Radiation Exposure at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable
NRC RG 8.10	Operating Philosophy for Maintaining Occupational Radiation Exposure As Low As Is Reasonably Achievable
NUREG 0700	Guidelines for Control Room Design Reviews
NUREG 0856	Final Technical Position on Documentation of Computer Codes for High-Level Waste Management
Presidential Memo (04/30/85)	Dispose of Defense Waste in a Commercial Repository

a. IAEA = International Atomic Energy Agency; EPA = Environmental Protection Agency; HLW = high-level radioactive waste; OCRWM = Office of Civilian Radioactive Waste Management.

b. This standard is complete, but has not been formally published at this time. However, it is included here as a source because it consists of a compilation of requirements from accepted sources. Those sources include standards from the Code of Federal Regulations, Nuclear Regulatory Commission regulations, and military, American National Standards Institute, National Aeronautics and Space Administration, and Electric Power Research Institute standards, as well as recognized design handbooks and guides that govern standard engineering practice.

REFERENCES

104618 Buchanan 1997 — Buchanan, C.C. 1997. "Final Biological Opinion for Reinitiation of Formal Consultation for Yucca Mountain Site Characterization Studies." Letter from C.C. Buchanan (Department of the Interior) to W. Dixon (DOE/YMSCO), July 23, 1997, File No. 1-5-96-F-307R. ACC: MOL.19980302.0368.

103189 DOE 1992 — DOE (U.S. Department of Energy) 1992. *Environmental Assessment for the Shipment of Low Enriched Uranium Billets to the United Kingdom from the Hanford Site, Richland, Washington.* DOE/EA-0787. Richland, Washington: U.S. Department of Energy. ACC: MOL.20010730.0389.

100018 National Research Council 1995 — National Research Council 1995. *Technical Bases for Yucca Mountain Standards.* Washington, D.C.: National Academy Press. TIC: 217588.

13. PREPARERS, CONTRIBUTORS, AND REVIEWERS

13.1 Preparers and Contributors

This chapter lists the individuals who filled primary roles in the preparation of this final environmental impact statement (EIS). Jane R. Summerson of the U.S. Department of Energy (DOE) Yucca Mountain Project Office directed the preparation of the EIS. Primary support and assistance to DOE was provided by the EIS Preparation Team, led by Joseph W. Rivers, Jr., of Jason Technologies Corporation; other members of the team included Tetra Tech NUS Inc., Battelle, and Dade Moeller & Associates. Judith A. Shipman coordinated the work of the Jason Technologies Corporation production team (Elisa Aguilar, Dalene Glanz, Laura Hall, Virginia Hutchins, Robin Klein, Evelyn Mayfield, Aaron McKinnon, and Janet McCreary). Dawn Siekerman supervised the EIS recordkeeping and reference support team (Marcia Gershin, Angelica Marquez, and Jessi Pagel). Glenn Caprio, assisted by Barbara Rhoads, provided scheduling support. Cynthia Langdale and Kathy Grebstad, under the supervision of Diane Morton, ensured EIS revision control accuracy.

DOE provided direction to the EIS Preparation Team, which was responsible for developing the analytical methodology and alternatives, coordinating the work tasks, performing the impact analyses, and producing the document. DOE was responsible for data quality, the scope and content of the EIS, and issue resolution and direction.

In addition, the Management and Operating Contractor to the DOE Yucca Mountain Site Characterization Office (Bechtel SAIC Corporation and its subcontractors) assisted in the preparation of supporting documentation and information for the EIS, as did Sandia, Argonne, and Oak Ridge National Laboratories. These organizations worked closely with the EIS Preparation Team under DOE direction.

DOE independently evaluated all supporting information and documentation prepared by these organizations. Further, DOE retained the responsibility for determining the appropriateness and adequacy of incorporating any data, analyses, and results of other work performed by these organizations in the EIS. The EIS Preparation Team was responsible for integrating such work into the EIS.

As required by Federal regulations (40 CFR 1506.5c), Jason Technologies Corporation and its subcontractors have signed NEPA Disclosure Statements in relation to the work they performed on this EIS. These statements appear at the end of this chapter.

Name	Education	Experience	Responsibility
		U.S. Department of Energy	
Jane R. Summerson	Ph.D., Geology, 1991 M.S., Geobiology, 1985 M.A., Anthropology, 1978 B.A., Anthropology, 1977	11 years – waste management projects with the DOE Office of Civilian Radioactive Waste Management	Document Manager
Robin L. Sweeney	Ph.D. student, Environmental Science and Public Policy M.S., Geosciences, 1987 B.S., Biological Sciences, 1980	22 years – hazardous and nuclear waste field; waste management, RCRA/CERCLA facility assessments, sampling and monitoring, project/program management, laboratory research	Senior Technical Specialist; NEPA Compliance Officer

Name	Education	Experience	Responsibility
Joseph D. Ziegler	B.S., Engineering (Nuclear), 1975	26 years – nuclear engineering, nuclear safety, environmental assessment, and project management; Federal and commercial nuclear projects	Senior Technical Advisor
M. Jozette Booth	B.S., Business Administration	18 years – transportation and policy analysis, communications and public participation, intergovernmental and Native American consultations	Technical lead for transportation and American Indian Programs
Wendy R. Dixon	Postgraduate studies, Geology and Environmental Science M.B.A., Business B.A., Sociology	21 years – management of nuclear-related projects; 14 years – regulatory compliance and field management; 6 years – safety and health	Senior Advisor for Environmental Policy
Kenneth J. Skipper	B.S., Geology, 1984	19 years – geotechnical/ environmental project management; Federal civil works projects; planning, construction, operations, and performance monitoring	Document Manager until March 2001
Final EIS Preparation Team			
Joseph W. Rivers, Jr. Jason Technologies Corporation	B.S., Mechanical Engineering, 1982	19 years – commercial and DOE nuclear projects; design, systems engineering, safety analysis, and regulatory compliance	Project Manager
David R. Wayman Jason Technologies Corporation	M.B.A., Business Administration, 1988 B.S., Construction Technology, 1980	20 years – commercial and DOE projects; construction engineering, nuclear safety analysis, environment compliance and permitting	Deputy Project Manager; Lead, Comment-Response Document
Diane E. Morton Jason Technologies Corporation	B.S., Chemical Engineering, 1979	21 years – DOE nuclear and environmental projects; project/program management, assessments, planning	Document Manager
John O. Shipman Jason Technologies Corporation	B.A., English Literature, 1966	35 years – NEPA documentation, technical writing and editing, publications management; 10 years – public participation	Document Production Manager, Editor; Comment-Response Document

Name	Education	Experience	Responsibility
Dawn Siekerman Jason Technologies Corporation	B.S., Biology, 1985	16 years – 3 years NEPA document preparation, 6 years environmental compliance/mixed waste project coordination/ quality assurance, 7 years inorganic chemistry	Records/Data Manager
Roseanne Aaberg Battelle – Pacific Northwest National Laboratories	B.S., Chemical Engineering, 1976	24 years – geological analysis; 11 years – environmental health physics	Air quality
Thomas Anderson Battelle Memorial Institute	B.S., Botany, 1973	28 years – preparation of DOE NEPA documents	Transportation
Pixie Baxter Tetra Tech NUS Inc.	M.B.A., Economics, 1981 B.A., Art History	20 years – multidisciplinary economic and business experience including 15 years as Economics College faculty member	Lead analyst, socioeconomics
William J. Berry Jason Technologies Corporation	Ph.D., Entomology, 1988 M.S., Biology, 1983 B.S., Biology, 1981	12 years – NEPA documents, ecological risk assessments, and habitat management plans	Lead analyst, biological resources
Ralph E. Best Jason Technologies Corporation	M.B.A., 1981 M.S., Electrical Engineering, 1970 B.S., Engineering Physics, 1964	36 years – energy, transportation, and environmental technology	Lead analyst, transportation
Carol Cole Jason Technologies Corporation	B.S., Experimental Psychology, 1967	20 years – NEPA documents, communications, public participation, media planning	Comment-Response Document
William J. Craig Dade Moeller & Associates	M.S., Planning, 1977 B.S., Forestry, 1972	22 years – environmental project management, nuclear fuel planning and analyses, natural resource management, and nuclear powerplant siting and relicensing	Comment-Response Document
David Crowl Jason Technologies Corporation	B.A., Computer Science, 1985	16 years – editing and document production	Editor

Name	Education	Experience	Responsibility
Keith D. Davis, PE Jason Technologies Corporation	M.S., Civil and Environmental Engineering, 1976 B.S., Civil Engineering, 1973	25 years – civil and environmental engineering; waste management; facility permitting and closure; site investigations, feasibility studies, and remedial action planning; 8 years – NEPA documentation	Hydrology; soils
Peter R. Davis Jason Technologies Corporation	Oak Ridge School of Reactor Technology, 1962 B.S. Physics, 1961	38 years – nuclear reactor and nuclear facility safety analysis and risk assessment	Lead analyst, accidents, inventory
Ted B. Doerr Jason Technologies Corporation	Ph.D., Wildlife and Fisheries Sciences, 1988 M.S., Range Science, 1980 B.S., Wildlife and Fisheries Sciences, 1977	19 years – NEPA implementation, ecology, environmental and ecological risk assessments, mitigation development, and regulatory compliance	Project Manager, Draft EIS
Sara A. Doersam Jason Technologies Corporation	B.A., Psychology, 1982	9 years – editing and publishing; 14 years – health administration	Editor
Paul W. Eslinger Battelle – Pacific Northwest National Laboratories	Ph.D., Statistics, 1983 M.A., Mathematics, 1978 B.S., Mathematics, 1976	18 years – environmental risk and human and ecological risk analysis	Long-term performance analysis
Suzanne Fiscus Jason Technologies Corporation	B.S., Mechanical Engineering, 1987	12 years - DOE nuclear projects; safety analysis, design and testing, waste characterization	Offsite manufacturing of disposal containers, shipping casks, drip shields, emplacement pallets, and related components
Philip C. Fulmer Dade Moeller & Associates	Ph.D., Nuclear Engineering, 1993 M.S., Health Physics, 1990 B.S., Health Physics, 1989	7 years – preparation of NEPA documents; 12 years – radiation protection, internal radiation dosimetry, external radiation dosimetry	Lead analyst, cumulative impacts
Gary Gunter Tetra Tech NUS Inc	B.S., Geology, 1984	5 years – preparation of NEPA documents; 13 years – assessments, remedial action	Lead analyst, land use; aesthetics

Name	Education	Experience	Responsibility
Ernest C. Harr, Jr. Jason Technologies Corporation	B.S., Zoology/Chemistry, 1977	12 years – preparation of NEPA documents; acted as DOE EM Headquarters NEPA Compliance Officer; reviewed many DOE waste management NEPA documents.	Deputy Project Manager, Draft EIS; Project Manager, 1999-2000
Mary N. Hoganson Tetra Tech NUS Inc.	M.S., Biology, 1989 B.S., Biology, 1984	14 years – waste management and waste minimization; 6 years – NEPA document preparation	Lead analyst, waste management and hazardous materials
Richard H. Holder Jason Technologies Corporation	M.B.A., Business Administration, 1986 M.S., Electrical Engineering, 1970 B.S., Electrical Engineering, 1966	33 years – team and line management for nuclear utility, industrial, and overseas projects	Proposed Action, alternatives, summary of findings and comparison
R. Kingsley House, PE Jason Technologies Corporation	M.S., Engineering Science/Nuclear Option, 1963 B.S., Mechanical Engineering, 1960 Nevada Registration No. 13062, 1997	40 years – nuclear and non-nuclear facility design, construction, testing, and operation; hazards analysis, safety analysis, and environmental impact analysis	Lead analyst, utilities, energy, materials, and site services; offsite manufacturing of disposal containers, shipping casks, drip shields, waste package supports, and related components
Tracy A. Ikenberry, CHP Dade Moeller & Associates	M.S., Radiology & Radiation Biology, 1982 B.A., Biology, 1979	19 years - environmental and occupational radiation protection; 7 years - NEPA document management and technical analysis	Lead analyst, short-term repository impacts, air quality; human health and safety
David H. Lester Jason Technologies Corporation	Ph.D., Chemical Engineering, 1969 M.S., Chemical Engineering, 1966 B.Che., Chemical Engineering, 1964	28 years – hazardous and nuclear waste management; nuclear Safety Analysis Reports, hazards analysis of waste storage operations, risk assessment of low-level nuclear waste burial operations, groundwater contamination transport modeling, performance assessment of high-level nuclear waste systems, design of treatment systems, design and analysis of high-level waste packages, and soil remediation studies	Lead Analyst, long-term performance

Name	Education	Experience	Responsibility
Steven Maheras Battelle Memorial Institute	Ph.D., Health Physics, 1988 M.S., Health Physics, 1985 B.S., Zoology, 1982 Certified Health Physicist, 1992	13 years – transportation risk assessment and radiological assessment; environmental and occupational radiation protection	Transportation
Thomas McSweeney Battelle Memorial Institute	Ph.D., Chemical Engineering, 1967 M.A., Mathematics, 1964 M.S., Chemical Engineering, 1961 B.S., Chemical Engineering, 1960	34 years – risk and safety analysis; 14 years – transportation risk analysis	Transportation
William E. Nichols Battelle – Pacific Northwest National Laboratories	M.S., Civil Engineering, 1990 B.S., Agricultural Engineering, 1987	12 years – subsurface flow and transport modeling and model development, environmental dispersion modeling and model development, probabilistic risk assessment, total systems modeling for geologic radioactive waste disposal evaluation, and NEPA documents	Long-term performance analysis
Paul R. Nickens Battelle – Pacific Northwest National Laboratories	Ph.D., Anthropology, 1977 M.A., Anthropology, 1974 B.A., Anthropology, 1969	25 years – cultural resource management and Native American consultation	Cultural resources
Donna L. Osborne Jason Technologies Corporation	20 years experience	20 years – technical editing, document production and coordination; 2 years – NEPA documentation	Editor
W. Kent Ostler Jason Technologies Corporation	Ph.D., Plant Ecology, 1979 M.S., Botany, 1976 B.S., Botany, 1974	22 years – plant ecology and arid land reclamation; identification of techniques to mitigate human impacts on biotic communities; surveys and research on endangered and threatened species; mitigation strategies for recovery of species	Biological resources

Name	Education	Experience	Responsibility
Ted M. Poston Battelle – Pacific Northwest National Laboratories	M.S., Fisheries, 1978 B.A., Biology,1973	19 years – noise analysis; 26 years – environmental research and toxicology; 24 years – NEPA experience	Lead analyst, noise and ground vibration
Eugene M. Rollins Dade Moeller & Associates	M.S.P.H., Health Physics, 1976 B.S., Nuclear Engineering, 1973	25 years – technical and management experience in health physics and risk assessments related to the nuclear fuel cycle	Lead analyst, No-Action Alternative
Steven B. Ross Battelle Memorial Institute	M.S., Nuclear Engineering, 1987 B.S., Nuclear Engineering, 1985	16 years – safety analysis, risk assessment, transportation, regulatory analysis, and fire risk assessment	Transportation
Dillard B. Shipler Battelle Memorial Institute	M.S., Major in Physics, 1967 B.S., Major in Science & Math, 1957 Certified Health Physicist, 1983	40 years – environment, safety, and health protection; occupational health and safety; radiation protection; high-level waste management; risk assessment; regulatory compliance; NEPA; systems engineering; and project/program management.	Transportation; Comment-Response Document
Judith A. Shipman Jason Technologies Corporation	A.A., General Studies, 1991	26 years – NEPA documentation, document production coordination, editing	Production Coordinator, Editor; Comment-Response Document
Sandra Snyder Battelle Memorial Institute	M.S.P.H., Radiological Hygiene, 1991 B.S., Environmental Resource Management, 1986	10 years – assessment of environmental and occupational exposure to radionuclides and chemicals	Air quality
Dennis Strenge Battelle Memorial Institute	M.S., Chemical Engineering, 1968 B.S., Chemical Engineering	33 years – environment exposure analysis and dosimetry for accidental and chronic releases of radionuclides and chemicals	Accidents
Lucinda Low Swartz Battelle Memorial Institute	J.D., 1979 B.A., Political Science and Administrative Studies, 1976	21 years – environmental law and regulation, specializing in NEPA compliance	Summary

Name	Education	Experience	Responsibility
John E. von Reis Jason Technologies Corporation	J.D., 1969 B.A., English (Prelegal), 1966	28 years – energy, environmental, resource and regulatory issues	Lead analyst, purpose and need, regulatory requirements, mitigation, unavoidable adverse impacts, environmental justice
Dee H. Walker Jason Technologies Corporation	Ph.D., Chemical Engineering, 1963 M.S., Chemical Engineering, 1962 Oak Ridge School of Reactor Technology, 1954 B.S., Chemical Engineering, 1953	48 years – nuclear engineering; 11 years – effects of radiological releases on humans and the environment	Health and safety
Jeffrey L. Weiler Jason Technologies Corporation	M.S., Resource Economics/ Environmental Management, 1974 B.A., Political Science, 1970	28 years – management of large interdisciplinary project teams; interagency coordination; stakeholder involvement; NEPA compliance	Document Manager, Draft EIS; Comment-Response Document
Ruth Weiner Jason Technologies Corporation	Ph.D., Chemistry, 1962 M.S., Chemistry, 1959 M.S., Physics, 1957 B.S., Physics, 1956	14 years – risk assessment of airborne pollutants and transportation risks, decision analysis; 25 years – environmental impact assessment; 35 years – professor of chemistry and environmental studies; 15 years – radioactive waste disposal, radioactive waste policy and regulation	Transportation
Thomas J. Winnard Battelle Memorial Institute	B.S., Geology, 1984	12 years – information systems	Transportation

13.2 Reviewers

The DOE Yucca Mountain Project Office incorporated input into the preparation of this EIS from a number of other DOE offices that reviewed the document while it was under development. These included the Offices of Environmental Management, Naval Reactors, Nuclear Energy, Materials Disposition, the National Spent Fuel Program, and the National High-Level Waste Program. The DOE Yucca Mountain Site Characterization Office, Nevada Operations Office, Idaho National Engineering and Environmental Laboratory, Hanford Site, and Savannah River Site also participated in the reviews of this EIS. In addition, personnel on assignment to the Yucca Mountain Project Office from the U.S. Department of the Interior Bureau of Reclamation provided technical review and other support, as did personnel from the DOE Office of Civilian Radioactive Waste Management Technical Support Services Contractor (Booz-Allen & Hamilton and its subcontractors).

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows. (check either (a) or (b) and list financial or other interest if (b) is checked)

(a) ☑ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By:

[signature]
Signature

James S. Holm
Name (Printed)

Director of Contracts
Title

Jason Associates Corporation
Company

June 7, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR PREPARATION OF THE ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

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In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows: (check either (a) or (b) and list financial or other interest if (b) is checked).

(a) ☑ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified by:

[signature]
Signature

Janet M. Mandel
Name (Printed)

Manager, Contract Operations
Title

Tetra Tech NUS, Inc.
Company

June 4, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

"Financial or other interest in the outcome of the project" includes "any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients)". See 46 FR 18026-18031.

In accordance with these requirements, the offeror and the proposed subcontractors hereby certify as follows. (check either (a) or (b) and list financial or other interest if (b) is checked)

(a) ☒ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By: [signature]
Signature

RALPH K. HENRICKS
Name (Printed)

CONTRACTING OFFICER
Title

BATTELLE MEMORIAL INSTITUTE
COLUMBUS OPERATIONS
Company

June 7, 1999
Date

QUALIFICATION CRITERION NO. 1

NEPA DISCLOSURE STATEMENT FOR
PREPARATION OF THE
ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA

CEQ Regulations at 40 CFR 1506.5(c), which have been adopted by the DOE (10 CFR 1021), require contractors who will prepare and EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project" for purpose of this disclosure is defined in the March 23, 1981, guidance "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations", 46 FR 18026-18038 at Question 17a and b.

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(a) ☒ Contractor has no financial or other interest in the outcome of the project.

(b) ☐ Offeror and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to award of this contract.

Financial or Other Interest

1.

2.

3.

Certified By:

[signature]
Signature

Matthew P. Moeller
Name (Printed)

Vice President
Title

Dade Moeller & Assoc.
Company

June 4, 1999
Date

14. GLOSSARY

(Note: A number of the terms in the Glossary emphasize their project-specific relationship to the Yucca Mountain Repository EIS. Words in *italics* refer to other words in the glossary.)

10,000-year peak of the mean annual dose

For this EIS, the largest annual *dose* analyzed within the first 10,000 years. See *peak of the mean annual dose (post-10,000 years)*.

100-year flood

A flood event of such magnitude that it occurs, on average, every 100 years; this equates to a 1-percent chance of its occurring in a given year.

500-year flood

A flood event of such magnitude that it occurs, on average, every 500 years; this equates to a 0.2-percent chance of its occurring in a given year.

A-weighted decibel scale

See *decibel, A-weighted*.

accessible environment

For this EIS, all points on Earth outside the surface and subsurface area controlled over the long term for the repository, including the atmosphere above the *controlled area*.

accident

An unplanned sequence of events that results in undesirable consequences. Examples in this EIS include an inadvertent release of *radioactive* or hazardous materials from their containers or *confinement* to the *environment*; vehicular accidents during the transportation of highly radioactive materials; and industrial accidents that could affect workers in the facilities.

acre-foot

The volume of water required to cover 1 acre to a depth of 1 foot (about 1,200 cubic meters or 330,000 gallons).

actinide

Any one of a series of chemically similar elements of *atomic numbers* 89 (actinium) through 103 (lawrencium). All actinides are *radioactive*.

active institutional control

Continued Federal control of the Yucca Mountain Repository site including access control, maintenance, monitoring, and surveillance of facilities and waste. See *institutional control*.

aerosol

A suspension of tiny, *colloid*-size particles or liquid droplets in air. Fog and smoke are common examples of aerosols.

affected environment

For an EIS, a description of the existing *environment* (that is, site description) covering information that relates directly to the scope of the *Proposed Action*, the *No-Action Alternative*, and the *implementing alternatives* being analyzed; in other words, the information necessary to assess or understand the *impacts*. This description must contain enough detail to support the impact analysis. The information must highlight "environmentally sensitive resources," if present; these include floodplains and wetlands, *threatened* and *endangered species*, prime and unique agricultural lands, and property of historic, archaeological, or architectural significance.

aging

Retaining *commercial spent nuclear fuel* on the surface at the proposed repository for future emplacement in an underground *drift*. DOE could retain the spent nuclear fuel in either wet or dry storage. If the Department used dry storage, it would place the spent nuclear fuel in a storage module licensed by the Nuclear Regulatory Commission.

affected unit of local government

The unit local government with jurisdiction over the site of a repository or a monitored retrievable storage facility. This term may, at the discretion of the Secretary of Energy, include units of local government that are contiguous with such unit. For the proposed, Yucca mountain Repository, the affected units of local government are Nye County, which has jurisdiction over the repository site and counties contiguous to Nye county (that is, Clark, Lincoln, White Pine, Eureka, Lander, Churchill, Mineral, and Esmeralda Counties in Nevada and Inyo County in California).

air lock

A chamber or room in which air pressure can be regulated, usually between two regions of unequal pressure. The isolation air locks each consist of two *bulkheads* with doors that open and close in sequence.

air quality

A measure of the concentrations of pollutants, measured individually, in the air.

ALARA

See *as low as reasonably achievable.*

alcove

A small excavation (room) off the main tunnel of a repository used for scientific study or for installing equipment.

alien species

With respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.

alignment

As used in the transportation analysis in this EIS, the location of a rail line in a *corridor*.

alkali flat

A level area or plain in an *arid* or semiarid region encrusted with alkali salts that become concentrated by evaporation and poor drainage. *Cap.* (Alkali Flat): An example of such terrain, approximately 25 miles south of the location in Amargosa Valley formerly known as Lathrop Wells along the Amargosa River.

alkalinity

Acid-neutralizing capacity of a substance. High alkalinity conditions can promote metal *corrosion*.

Alloy-22

A *corrosion*-resistant, high-nickel alloy used for the outer shell of the *disposal container/waste package*, and for the parts of the emplacement pallet that would contact the waste package.

alluvial fan

A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream where it issues from a narrow mountain valley on a plain or broad valley.

alluvium

Sedimentary material deposited by flowing water.

alpha particle

A positively charged particle ejected spontaneously from the *nuclei* of some *radioactive* elements. It is identical to a helium nucleus and has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). See *ionizing radiation.*

alternate

As used in the transportation analysis in this EIS, a variation of a rail corridor segment to mitigate a potential adverse environmental or engineering factor. See *variation*, *option*, *corridor*.

alternative

One of two or more actions, processes, or propositions from which a *decisionmaker* will determine the course to be followed. The *National Environmental Policy Act*, as amended, states that in preparing an EIS, an agency "shall ... (s)tudy, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" [42 U.S.C. 4321, Title I, Section 102 (E)]. The regulations of the Council on Environmental Quality that implement the National Environmental Policy Act indicate that the alternatives section in an EIS is "the heart of the environmental impact statement" (40 CFR 1502.14), and include rules for presenting the alternatives, including no action, and their estimated impacts.

This EIS has two alternatives: the *Proposed Action* under which DOE would construct, operate and monitor, and eventually close a *monitored geologic repository* for the *disposal* of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain, and the *No-Action Alternative* under which DOE would end *site characterization* activities at Yucca Mountain, and spent nuclear fuel and high-level radioactive waste at commercial storage sites and DOE facilities would continue to accumulate. The *Nuclear Waste Policy Act* states that this EIS does not have to discuss alternatives to geologic disposal or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the Proposed Action. See *implementing alternative*.

DOE will base its decision on whether the repository program should proceed toward a site recommendation for Yucca Mountain in part on the Final EIS.

Amargosa Desert

The basin area lying south of Beatty, Nevada, and extending southeast some 80 kilometers (50 miles) to the area of Alkali Flat in California. The unincorporated Town of Amargosa Valley, Nevada, lies in the central portion of Amargosa Desert. Amargosa Desert is also the name of *hydrographic area* number 230 which is part of the Death Valley Groundwater Region; both are designations used by the State of Nevada in its water planning and appropriations efforts. The boundaries of the Amargosa Desert hydrographic area closely resemble those of the geographic area.

Amargosa River

The main drainage system of the *Amargosa Desert*. The Amargosa River drainage basin originates in the Pahute Mesa-Timber Mountain area north of Yucca Mountain and includes the main tributary systems of *Beatty Wash* and *Fortymile Wash*. The river, which is frequently dry along much of its length, flows southeastward through the Amargosa Desert and ends in the internal drainage system of Death Valley.

ambient

(1) Undisturbed, natural conditions such as ambient temperature caused by climate or natural *subsurface* thermal gradients. (2) Surrounding conditions.

ambient air

The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in the immediate proximity to emission sources.

ambient air quality standards

Standards established on a Federal or state level that define the limits for airborne concentrations of designated *criteria pollutants* [nitrogen dioxide, *sulfur dioxide*, *carbon monoxide*, *particulate matter* with aerodynamic diameters less than 10 microns (PM_{10}), *ozone*, and lead] to protect public health with an adequate margin of safety (primary standards) and to protect public welfare, including plant and animal life, visibility, and materials (secondary standards). See *criteria pollutants.*

analyzed land withdrawal area

See *land withdrawal area.*

aquifer

A *subsurface* saturated rock unit (formation, group of formations, or part of a formation) of sufficient *permeability* to transmit *groundwater* and yield usable quantities of water to wells and springs.

aquitard

A rock unit or layer or layer that stores water and allows it to move only at a very slow rate.

areal mass loading

As used in *thermal loading* calculations, the amount of *heavy metal* (usually expressed in metric tons of uranium or equivalent) emplaced per unit area in the proposed repository.

arid

(1) Areas where mean annual evaporation exceeds mean annual precipitation; (2) having insufficient rainfall to support agriculture; (3) the hyper-arid zone (arid index 0.03) comprises dryland areas without vegetation with the exception of a few scattered shrubs. Annual rainfall is low, rarely exceeding 100 millimeters (4 inches). In the arid zone (arid index 0.03-0.20), the native vegetation is sparse, being comprised of annual and perennial grasses and other herbaceous vegetation, and shrubs and small trees. There is high rainfall variability, with annual amounts ranging between 100 and 300 millimeters (4 and 12 inches).

as low as reasonably achievable
A process that applies a graded approach to reducing *dose* levels to workers and the public, and releases of *radioactive* materials to the *environment*. The goal of this process, often referred to as ALARA, is not merely to reduce doses, but to reduce them to levels that are as low are reasonable achievable.

assembly
See *fuel assembly*.

atmospheric dispersion
Movement of a *contaminant* as a result of the cumulative effect of the wind patterns and random motions of the air.

atomic mass
The mass of a neutral atom, based on a relative scale, usually expressed in atomic mass units. See *atomic weight.*

atomic number
The number of protons in an atom's nucleus.

atomic weight
The relative mass of an atom based on a scale in which a specific carbon atom (carbon-12) is assigned a mass value of 12. Also known as relative *atomic mass*.

autolytic criticality
A transient *criticality* in which the usual mechanisms that tend to shut down a criticality are delayed until a high *fission* rate is achieved.

backfill
The general fill that is placed in the excavated areas of an underground facility. Backfill for the proposed repository could be *tuff* or other material.

background radiation
Radiation from cosmic sources, naturally occurring *radioactive* materials such as granite, and global fallout from nuclear testing.

Bare Mountain
An upfaulted mountain block that bounds the west side of *Crater Flat*.

barrier
Any material, structure, or condition (as a thermal barrier) that prevents or substantially delays the movement of water or *radionuclides*. See *natural barrier*.

basalt
A dark gray to black, dense to fine-grained *igneous* rock.

baseline
Documentation of current conditions so that changes can be identified.

Beatty Wash

A tributary drainage to the *Amargosa River*; drains the west and north sides of the Yucca Mountain area.

berm

A mound or wall of earth.

beta particle

A negatively charged *electron* or positively charged positron emitted from a *nucleus* during decay. Beta decay usually refers to a radioactive transformation of a nuclide by electron emission, in which the atomic number increases by 1 and the mass number remains unchanged. In positron emission, the atomic number decreases by 1 and the mass number remains unchanged. See *ionizing radiation.*

biosphere

The ecosystem of the Earth and the living *organisms* inhabiting it.

blending

See *fuel blending.*

block-bounding fault

A high-angle, normal fault with relatively large displacement that bounds one or both sides of the fault-block mountains typical of the Basin and Range province.

boiling-water reactor (BWR)

A *nuclear reactor* that uses boiling water to produce steam to drive a turbine.

borehole

For this EIS, a hole drilled for purposes of collecting *site characterization* data or for supplying water.

borosilicate glass

High-level radioactive waste matrix material in which boron takes the place of the lime used in ordinary glass mixtures.

borrow areas

Areas outside the rail corridor where construction personnel could obtain materials to be used in the establishment of a stable platform (subgrade) for the rail track. Aggregate crushing operations could occur in these areas.

buffer cars

Railcars in front of or in back of those carrying *spent nuclear fuel* and *high-level radioactive waste* to provide additional distance to possibly occupied railcars or to railcars carrying hazardous materials other than *radioactive* materials. Federal regulations require the separation of a railcar carrying spent nuclear fuel and high-level radioactive waste from a locomotive, occupied caboose, carload of undeveloped film, or railcar carrying another class of hazardous material by at least one buffer car. These could be DOE railcars or, in the case of general freight service, commercial railcars.

bulkhead
A wall or embankment in a mine or tunnel that protects against earthslide, fire, water, or gas.

burnup
A measure of *nuclear reactor* fuel consumption expressed either as the percentage of fuel atoms that have undergone *fission* or as the amount of energy produced per unit weight of fuel.

caldera
An enlarged volcanic crater formed by explosion or collapse of the original crater.

cancer
A malignant tumor of potentially unlimited growth, capable of invading surrounding tissue or spreading to other parts of the body.

candidate species
Species for which the U.S. Fish and Wildlife Service has enough substantive information on biological status and threats to support proposals to list them as threatened or endangered under the Endangered Species Act. Listing is anticipated but has been precluded temporarily by other listing activities.

canister
An unshielded metal container used as: (1) a pour mold in which molten vitrified *high-level radioactive waste* can solidify and cool; (2) the container in which DOE and electric utilities place intact *spent nuclear fuel*, loose rods, or nonfuel components for shipping or storage; or (3) in general, a container used to provide radionuclide *confinement*. Canisters are used in combination with specialized overpacks that provide structural support, shielding or confinement for storage, transportation, and *emplacement*. Overpacks used for transportation are usually referred to as transportation *casks*; those used for emplacement in a repository are referred to as *waste packages*.

capillary barrier
A contact in the *unsaturated zone* between a *geologic* unit containing relatively small-diameter openings and a unit containing relatively large-diameter openings across which water does not flow.

carbon monoxide
A colorless, odorless, poisonous gas produced by incomplete fossil-fuel combustion; one of the six pollutants for which there is a national *ambient air quality standard*.

carbon steel
A steel that is tough but malleable and contains a small percentage of carbon. The inner *barrier* of *waste packages* is composed of carbon steel.

carcinogen
An agent capable of producing or inducing *cancer*.

carcinogenic
Capable of producing or inducing *cancer*.

cask

(1) A heavily shielded container that meets applicable regulatory requirements used to ship *spent nuclear fuel* or *high-level radioactive waste*; (2) a heavily shielded container used by DOE and utilities for the *dry storage* of spent nuclear fuel; usable only for storage, not for transportation to or *emplacement* in a repository.

chain reaction

A process in which some of the *neutrons* released in one *fission* event cause other fission events that in turn release *neutrons*.

characterization

Activities in the laboratory or the field undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository. These activities include borings, surface excavations, excavations of exploratory shafts, limited *subsurface* lateral excavations and borings, and *in situ* testing to evaluate the suitability of a candidate site for the location of a repository, but do not include preliminary borings and geophysical testing to assess if *site characterization* should be undertaken.

Civilian Radioactive Waste Management System

The organizational system of the DOE Office of Civilian Radioactive Waste Management; it is the composite of the sites and all facilities, systems, equipment, materials, information, activities, and personnel required to perform the activities necessary to manage *radioactive* waste *disposal*.

cladding

The metallic outer sheath of a fuel element generally made of stainless steel or a *zirconium alloy*. It is intended to isolate the fuel element from the external *environment*.

clastic

Describing a rock or sediment composed mainly of broken fragments of preexisting minerals or rocks that have been transported from their places of origin.

climate states

Representations of climate conditions. Six different climate states are used to represent changes in climate over the periods of interest: Interglacial Climate (the same as present-day), Glacial-Transition (also known as Intermedial Climate), Intermediate/Monsoon Climate, Glacial Climate Stage 8/10, Glacial Climate Stage 6/16, and Glacial Climate Stage 4.

closure

See *repository phases*.

co-disposal

A packaging method for *disposal* of *radioactive* waste in which two types of waste, such as *commercial spent nuclear fuel* and defense *high-level radioactive waste*, are combined in *disposal containers*. Co-disposal takes advantage of otherwise unused space in disposal containers and is more cost-effective than other methods to limit the reactivity of individual *waste packages*.

collective dose

See *population dose*.

colloid

Small particles in the size range of 10^{-9} to 10^{-6} meters that are suspended in a solvent. Naturally occurring colloids in *groundwater* arise from clay minerals.

colluvium

Loose earth material that has accumulated at the base of a hill, through the action of gravity.

commercial spent nuclear fuel

Commercial nuclear fuel rods that have been removed from *reactor* use. See *spent nuclear fuel* and *DOE spent nuclear fuel*.

conceptual model

A set of *qualitative* assumptions used to describe a system or subsystem for a given purpose. Assumptions for the model should be compatible with one another and fit the existing data within the context of the given purpose of the model.

confinement

As it pertains to *radioactivity*, the retention of *radioactive* material within some specified bounds. Confinement differs from containment in that there is no absolute physical *barrier* in the former.

construction

See *repository phases*.

construction/demolition debris

Discarded solid wastes resulting from the construction, remodeling, repair, and demolition of structures, road building, and land clearing that are inert or unlikely to create an environmental hazard or threaten the health of the general public. Such debris from repository construction would include materials such as soil, rock, masonry materials, and lumber.

construction support areas

Areas along the rail route that could be used as temporary residences for construction crews, material and equipment storage areas, and concrete production areas. Such camps probably would be for the construction of routes far from population centers.

contaminant

A substance that contaminates (pollutes) air, soil, or water. Also, a hazardous substance that does not occur naturally or that occurs at levels greater than those that occur naturally in the surrounding *environment*.

contaminant flux

Movement of a *contaminant* across a surface boundary per unit time (for example, *curies* per year; milligrams per year).

contamination

The intrusion of undesirable elements (unwanted physical, chemical, biological, or radiological substances, or matter that has an adverse effect) to air, water, or land.

controlled area

The area restricted for the long term for the repository, as identified by passive institutional controls DOE would install at *closure*. The controlled area is 300 square kilometers (about 120 square miles) maximum surface and subsurface area that extends in the predominant direction of groundwater flow no farther south than 36 degrees, 40 minutes, 13.6661 seconds north latitude (the present southwest corner of the Nevada Test Site), and no more than 5 kilometers (3 miles) from the repository footprint in any other direction. (See 40 CFR 197.12.)

convection
: (1) Thermally driven *groundwater* flow or a heat-transfer mechanism for a gas phase. The bulk motion of a flowing fluid (gas or liquid) in the presence of a gravitational field, caused by temperature differences that, in turn, cause different areas of the fluid to have different densities (for example, warmer is less dense). (2) One of the processes that moves solutes in *groundwater*.

corridor
: As used in the transportation analysis in this EIS, a strip of land, approximately 400 meters (0.25 mile) wide, that encompasses one of several possible routes through which DOE could build a branch rail line to transport *spent nuclear fuel*, *high-level radioactive waste,* and other material to and from the proposed Yucca Mountain Repository.

corrosion
: The process of dissolving or wearing away gradually, especially by chemical action.

corrosion-resistant material
: *Disposal container* material, such as Alloy-22, that oxidizes slowly in a corrosive environment.

cosmic radiation
: A variety of high-energy particles including protons that bombard the Earth from outer space. They are more intense at higher altitudes than at sea level where the Earth's atmosphere is most dense and provides the greatest protection.

cosmogenic radionuclides
: Radioactive nuclides generated when the upper atmosphere interacts with many of the cosmic radiations. Common cosmogenic radionuclides include carbon-14, tritium, and beryllium-7.

Crater Flat
: A north-trending, 6- to 11-kilometer (4- to 7-mile)-wide area west of Yucca Mountain; bounded by *Bare Mountain* on the west and Yucca Mountain on the east.

credible event/credible accident
: An event or *accident* scenario that the design of the *geologic repository* considers reasonably foreseeable with a possibility of at least 1 in 10 million.

criteria pollutants
: Six common pollutants (*ozone*, *carbon monoxide*, *particulates*, *sulfur dioxide*, lead, and nitrogen dioxide) known to be hazardous to human health and environment and for which the U.S. Environmental Protection Agency sets National Ambient Air Quality Standards under the Clean Air Act. See *toxic air pollutants*.

criticality
: The condition in which nuclear fuel sustains a *chain reaction*. It occurs when the number of neutrons present in one generation cycle equals the number generated in the previous cycle.

criticality control

Set of measures taken to maintain nuclear materials, including *spent nuclear fuel*, in a *subcritical* condition during storage, transportation, and *disposal*, so no self-sustaining nuclear *chain reaction* can occur. Subcriticality is maintained by loading spent nuclear fuel in specific configurations that meet requirements related to fuel age, enrichment, and reduction in nuclear fuel reactivity through *burnup*.

cross drift

An approximately 2,800-meter (9,200-foot)-long *drift* excavated to provide researchers new opportunities to study the geologic profile of the rock in the proposed repository area beneath Yucca Mountain. Researchers will conduct a new battery of tests in the cross drift as part of ongoing studies to determine if Yucca Mountain would be a suitable host for a deep *monitored geologic repository* for *spent nuclear fuel* and *high-level radioactive waste*. The cross drift begins inside the *Exploratory Studies Facility* approximately 2,000 meters (6,600 feet) from the northern entrance and cuts through the entire stratigraphic section of the potential Upper Block emplacement area.

crud

The *radionuclide* contribution from activated *corrosion* products deposited on the surfaces of *fuel assemblies* during reactor operations.

cumulative impact

The *impact* on the *environment* that results from the incremental impact(s) of an action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

curie

A unit of *radioactivity* equal to 37 billion *disintegrations* per second.

decay (radioactive)

The process in which one radionuclide spontaneously transforms into one or more different radionuclides called decay products.

decibel (dB)

A standard unit for measuring sound-pressure levels based on a reference sound pressure of 0.0002 dyne per square centimeter. This is the smallest sound a human can hear.

decibel, A-weighted (dBA)

A measurement of sound approximating the sensitivity of the human ear and used to characterize the intensity or loudness of sound.

decisionmaker

The group or individual responsible for making a decision on constructing and operating a *monitored geologic repository* for the disposal of *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain.

decommissioning
: The process of removing from service a facility in which nuclear materials are handled. It usually involves decontaminating the facility so that it may be dismantled or dedicated to other purposes.

decontamination
: A process that removes, destroys, or neutralizes chemical, biological, or radiological contamination from a person, object, or area.

dedicated freight rail service
: A train that handles only one commodity (in this case, *spent nuclear fuel* or *high-level radioactive waste*); this separate train with its own crew would limit switching between trains of the railcars carrying these materials.

defense-in-depth
: (1) A design strategy based on a system of multiple, independent, and redundant *barriers*, designed to ensure that failure in any one barrier does not result in failure of the entire system. (2) The term used to describe a system of multiple barriers that mitigate *uncertainties* in conditions, processes, and events.

deformation
: A change in the shape and size of a body.

design alternative
: A fundamentally different conceptual design for a repository, which could stand alone as the License Application repository design concept.

design-basis event
: Naturally or humanly induced events that are reasonably likely to occur one or more times before permanent closure of the *geologic repository's* operations area; in addition, any other natural or human-induced event that is unlikely, but is sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on public health and safety.

design enhancement
: An engineered *barrier* system feature that DOE is considering for possible inclusion in the design for the Yucca Mountain Repository. Design enhancements are not considered to be essential to the successful performance of the repository. The EIS analysis of the *Proposed Action* will not include design enhancements, but will identify them as possible means of *mitigation*. If a design enhancement is added to the reference design in time for inclusion in the EIS, it will be evaluated as part of the Proposed Action design.

deterministic
: A single calculation using only a single value for each of the model parameters. A deterministic system is governed by definite rules of system behavior leading to cause and effect relationships and predictability. Deterministic calculations do not account for *uncertainty* in the physical relationships or parameter values.

dip-slip fault

A fault in which the relative displacement is along the direction of dip of the fault plane. If the block above the fault has moved downward it is a *normal fault*; upward movement indicates a *reverse fault*.

direct impact

Effect that results solely from the construction or operation of a proposed action without intermediate steps or processes. Examples include habitat destruction, soil disturbance, air emissions, and water use.

discretization

The process of dividing geometry into smaller pieces (finite elements) to prepare for analysis. For example, for the EIS analysis DOE divided the broad volume of the *unsaturated zone* beneath the proposed repository into smaller portions, each of which has its own set of characteristics, to model water flow and potential transport of *radionuclides* from the repository to the *saturated zone*.

disintegration

Any transformation of a *nucleus*, whether spontaneous or induced by *irradiation*, in which the nucleus emits one or more particles or *photons*.

disposable canister

A metal vessel for commercial or DOE *spent nuclear fuel* assemblies or solidified *high-level radioactive waste* with specialized overpacks to enable storage, transportation, and *emplacement* in a repository.

disposal

The *emplacement* in a repository of *high-level radioactive waste*, *spent nuclear fuel*, or other highly *radioactive* material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the *isolation* of such waste from the *accessible environment*.

disposal container

The vessel consisting of the *barrier* materials and internal components in which the canistered or uncanistered waste form would be placed. The disposal container would include the container barriers or shells, spacing structures or baskets, shielding integral to the container, packing contained within the container, and other absorbent materials designed to be placed internal to the container or immediately surrounding the disposal container (that is, attached to the outer surface of the container). The filled, sealed, and tested disposal container is referred to as the *waste package*, which would be emplaced in the repository.

disproportionately high and adverse environmental impacts

An environmental *impact* that is unacceptable or above generally accepted norms; these would include economic impacts of the *Proposed Action*. A disproportionately high impact is one (or the risk of one) to a *low-income population* or *minority population* that significantly exceeds the impact to the general population. In assessing cultural and aesthetic impacts, agencies consider impacts that would have unique effects on geographically dislocated or dispersed low-income or minority populations.

disproportionately high and adverse human health effects

Effects that occur when *impacts* to a *minority population* or *low-income population* from exposure to an environmental hazard significantly exceed the impacts to the general population and, where available, to an appropriate comparison group.

disruptive event

An unexpected event which, in the case of the repository, includes *human intrusion*, volcanic activity, *seismic* activity, and nuclear *criticality*. Disruptive events have two possible effects: (1) direct release of *radioactivity* to the surface, or (2) alteration of the expected behavior of the system.

dissolution

Molecular dispersion of a solid in a liquid.

distribution

As used in analyses of long-term performance, a range of values and probabilities associated with each value (or subrange of values) within the range. This can be in the form of a mathematical function or a table of values. *See normal distribution.*

DOE spent nuclear fuel

Radioactive waste created by defense activities that consists of more than 250 different waste forms. The major contributor to this waste form is the N-Reactor fuel currently stored at the Hanford Site. This waste form also includes 65 MTHM of *naval spent nuclear fuel*.

dose

The amount of radioactive energy taken into (absorbed by) living tissues.

dose equivalent

(1) The number (corrected for background) zero and above that is recorded as representing an individual's *dose* from external *radiation* sources or internally deposited *radioactive* materials; (2) the product of the absorbed dose in *rads* and a quality factor; (3) the product of the absorbed dose, the quality factor, and any other modifying factor. The dose equivalent quantity is used for comparing the biological effectiveness of different kinds of radiation (based on the quality of radiation and its spatial distribution in the body) on a common scale; it is expressed in *rem*.

dose rate

The *dose* per unit time.

dose risk

The product of a radiation dose and the probability of its occurrence.

drift

From mining terminology, a horizontal underground passage. Includes excavations for *emplacement* (emplacement drifts) and access (access mains).

drip shield

A corrosion-resistant engineered *barrier* that would be placed above the *waste package* to prevent seepage water from directly contacting the waste packages for thousands of years. The drip shield would also offer protection to the waste package from rockfall.

dry storage

Storage of *spent nuclear fuel* without immersing the fuel in water for cooling or shielding; it involves the encapsulation of spent fuel in a steel cylinder that might be in a concrete or massive steel *cask* or structure.

dual-purpose canister

A metal vessel suitable for storing (in a storage facility) and shipping (in a shipping cask) commercial *spent nuclear fuel* assemblies. At the repository, dual-purpose canisters would be removed from the shipping cask and opened. The *spent nuclear fuel* assemblies would be removed from the canister and placed in a *disposal container* or in the fuel pool to accomodate *blending*. The opened canister would be recycled or disposed of offsite as low-level *radioactive* waste.

earthquake

A series of elastic waves in the crust of the Earth caused by abrupt movement easing strains built up along *geologic* faults or by volcanic action and resulting in movement of the Earth's surface.

electron

A stable elementary particle that is the negatively charged constituent of ordinary matter.

emplacement

The placement and positioning of *waste packages* in the repository emplacement *drifts*.

endangered species

A species that is in danger of extinction throughout all or a significant part of its range; a formal listing of the U.S. Fish and Wildlife Service under the Endangered Species Act.

Energy Policy Act of 1992 (Public Law 102-486, 106 Stat. 2776)

Legislation that amends the *Nuclear Waste Policy Act* by directing (1) the Environmental Protection Agency to set site-specific public health and safety radiation protection standards from Yucca Mountain, and (2) the Nuclear Regulatory Commission to modify its technical requirements and licensing criteria to be consistent with the Environmental Protection Agency site-specific standards.

engineered barrier system

The designed, or engineered, components of the underground facility, including the *waste packages* and other engineered *barriers*.

enhanced design alternative

A combination (or variation) of one or more design alternatives and design features.

environment

(1) Includes water, air, and land and all plants and humans and other animals living therein, and the interrelationship existing among these. (2) The sum of all external conditions affecting the life, development, and survival of an *organism*.

environmental impact statement (EIS)

A detailed written statement which describes:

> "...the environmental impact of the proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; alternatives to the proposed action (although the Nuclear Waste Policy Act, as amended, precludes consideration of certain alternatives); the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."

Preparation of an EIS requires a public process that includes public meetings, reviews, and comments, as well as agency responses to the public comments.

environmental justice

The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

environmental monitoring

The process of sampling and analyzing environmental media in and around a facility to (1) confirm compliance with performance objectives and (2) detect *contamination* entering the *environment* to facilitate timely remedial action.

environmental resource areas

Areas examined for potential environmental impacts as part of the *National Environmental Policy Act* analysis process. Examples include air quality, hydrology, and biological resources.

ephemeral

Used in this EIS in reference to a nonpermanent stream or other body of water.

equilibrium

The state of a chemical system in which the phases do not undergo any spontaneous change in properties or proportions with time; a dynamic balance.

erionite

A natural fibrous *zeolite* in the rocks at Yucca Mountain that is listed as a known human carcinogen by recognized international agencies such as the International Agency for Research on Cancer.

escort cars

Railcars in which escort personnel would travel on trains carrying *spent nuclear fuel* or *high-level radioactive waste*.

evapotranspiration

The combined processes of evaporation and plant *transpiration* that remove water from the soil and return it to the air.

Exploratory Studies Facility

An underground laboratory at Yucca Mountain that includes an 8-kilometer (5-mile) main loop (tunnel), a 3-kilometer (2-mile) *cross drift*, and a research *alcove* system constructed for performing underground studies during *site characterization*. The data collected will contribute toward determining the suitability of the Yucca Mountain site as a repository. Some or all of the facility could be incorporated into the proposed repository.

exposure (to radiation)

The incidence of *radiation* on living or inanimate material by accident or intent. Background exposure is the exposure to natural *ionizing radiation*. Occupational exposure is the exposure to ionizing radiation that occurs during a person's working hours. Population exposure is the exposure to a number of persons who inhabit an area.

exposure pathway

The course a chemical or physical agent takes from the source to the exposed *organism*; describes a unique mechanism by which an individual or population can become exposed to chemical or physical agents at or originating from a release site. Each exposure pathway includes a source or a release from a source, an exposure point, and an exposure route.

far-field

The area of the geosphere and *biosphere* far enough away from the repository that, when numerically modeled, releases from the repository are represented as a homogeneous, single-source effect.

fault

A *fracture* or a fracture zone in crustal rocks along which there has been movement of the fracture's two sides relative to one another, so that what were once parts of one continuous rock stratum or vein are now separated.

Fiscal Year

A 12-month period to which a jurisdiction's annual budget applies and at the end of which its financial position and the results of its operations are determined. For example, the Fiscal Year for Clark and Nye Counties, the Cities of Las Vegas and North Las Vegas, the Towns of Tonopah and Pahrump, and the Clark County and Nye County School Districts runs from July 1 through the following June 30; the Federal Fiscal Year runs from October 1 through the following September 30.

fission

The splitting of a *nucleus* into at least two other nuclei, resulting in the release of two or three *neutrons* and a relatively large amount of energy.

fission products

Radioactive or nonradioactive atoms produced by the *fission* of heavy atoms, such as uranium.

flexible design

As used in this EIS, the repository design and operating modes presented in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration*. See *higher-temperature repository operating mode* and *lower-temperature repository operating mode*.

floodplain

The lowlands adjoining inland and coastal waters and relatively flat areas and floodprone areas of offshore islands including, at a minimum, that area inundated by a 1 percent or greater chance flood in any given year. The base floodplain is defined as the 100-year (1.0-percent) floodplain. The critical action floodplain is defined as the 500-year (0.2-percent) floodplain.

Fortymile Wash

A major tributary to the *Amargosa River*; drains *Jackass Flats* to the east of Yucca Mountain; usually dry along most of its length.

fracture

A general term for any break in a rock, whether or not it causes displacement, caused by mechanical failure from stress. Fractures include cracks, joints, and *faults*. Fractures can act as pathways for rapid *groundwater* movement.

fuel assembly

A number of fuel elements held together by structural materials, used in a *nuclear reactor*. Sometimes called a fuel bundle.

fuel blending

The process of loading low-heat-output waste with high-heat-output waste in a *waste package* to balance its total heat output. This process would apply only to *commercial spent nuclear fuel*.

fugitive dust

Particulate matter composed of soil; can include emissions from haul roads, wind erosion of exposed soil surfaces, and other activities in which soil is removed or redistributed.

fugitive emissions

Emissions released directly into the *atmosphere* that could not reasonably pass through a stack, chimney, vent, or other functionally equivalent opening.

GENII

A *deterministic* computer software code that evaluates *dose* from the migration of radionuclides introduced into the *accessible environment*, or *biosphere*, that may eventually affect humans through ingestion, inhalation, or direct *radiation*. It is used to develop biosphere dose conversion factors.

gamma ray

The most penetrating type of radiant nuclear energy. It does not contain particles and can be stopped by dense materials such as concrete or lead. *See ionizing radiation.*

general freight rail service

Railroad line service that uses trains that move railcars, each of which might contain a different commodity. Railcars carrying *spent nuclear fuel* or *high-level radioactive waste* could be switched (in railyards or on sidings) successively from one general freight train to another as they traveled from the commercial and DOE locations to Nevada.

geologic

Of or related to a natural process acting as a dynamic physical force on the Earth (faulting, erosion, mountain building resulting in rock formations, etc.).

geologic repository

A system for disposing of *radioactive* waste in excavated *geologic* media, including surface and *subsurface* areas of operation, and the adjacent part of the geologic setting that provides *isolation* of the radioactive waste in the *controlled area*.

Great Basin

A subprovince of the Basin and Range province, generally characterized by north-trending mountain ranges and intervening basins, stretching from eastern Oregon to southern California.

Greater-Than-Class-C waste

Low-level nuclear waste generated by the commercial sector that exceeds U.S. Nuclear Regulatory Commission concentration limits for Class-C low-level waste, as specified in 10 CFR Part 61. DOE is responsible for disposing of this type of waste from its nondefense programs.

Gross Regional Product

The dollar value of all final goods and services produced in a given year in a specific region (such as the *region of influence*).

ground support

The system (rock bolts with wire mesh, steel structures, cast or precast concrete sections) used to line the main and emplacement *drifts* to minimize rock or earth falling into the drifts.

ground vibration

The rapid linear motion of a compression wave in the ground caused by a single or repeated force or impact to the ground as in the action of a pile driver or a tire hitting a bump or pothole in a road.

groundwater

Water contained in pores or fractures in either the *unsaturated zone* or *saturated zone* below ground level.

habitat

Area in which a plant or animal lives and reproduces.

half-life (radiological)

The time in which half the atoms of a *radioactive* substance decay to another nuclear form. Half-lives range from millionths of a second to billions of years depending on the stability of the nuclei.

hazardous chemical

As defined under the Occupational Safety and Health Act and the Community Right-to-Know Act, a chemical that is a physical or health hazard.

hazardous pollutant

Hazardous chemical that can cause serious health and environmental hazards, and listed on the Federal list of hazardous air pollutants (42 U.S.C. 7412). See *toxic air pollutants*.

hazardous waste

Waste designated as hazardous by Environmental Protection Agency or State of Nevada regulations. Hazardous waste, defined under the Resource Conservation and Recovery Act, is waste that poses a potential hazard to human health or the environment when improperly treated, stored, or disposed of. Hazardous wastes appear on special Environmental Protection Agency lists or possess at least one of the following characteristics: ignitability, corrosivity, toxicity, or reactivity. Hazardous waste streams from the repository could include certain used rags and wipes contaminated with solvents. (Note: The proposed Yucca Mountain Repository would not accept hazardous waste, either solid or liquid, and DOE would dispose of all repository-generated hazardous waste at offsite facilities.)

heavy-haul truck

An overweight, overdimension vehicle that must have permits from state highway authorities to use public highways; a vehicle DOE would use on public highways to move *spent nuclear fuel* or *high-level radioactive waste shipping casks* designed for a railcar.

heavy metal

All uranium, plutonium, and thorium used or generated in a manmade *nuclear reactor*.

high-efficiency particulate air filter

A filter with an efficiency of at least 99.95 percent that separates particles from an air exhaust stream before the air is released to the atmosphere.

higher-temperature repository operating mode

The *flexible design* would maintain the repository host rock temperatures below the boiling point of water [96°C (205°F) at the elevation of the repository] during the preclosure period with continuous ventilation of the *emplacement drifts*. After mechanical ventilation was discontinued at closure, host rock temperatures would increase above the boiling point of water, and moisture around the emplacement drifts would evaporate and be driven away from the drifts as water vapor. A boiling zone would develop around each emplacement drift, but it would not extend all the way across the *pillars*. This mode would allow percolation of moisture downward past the *emplacement horizon* through central portions of the rock pillars between the drifts. See *lower-temperature repository operating mode.*

high-level radioactive waste

(1) The highly *radioactive* material that resulted from the reprocessing of *spent nuclear fuel*, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains *fission* products in sufficient concentrations. (NOTE: DOE would vitrify liquid *high-level radioactive waste* before shipping it to the repository.) (2) Other highly radioactive material that the Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent *isolation*.

Highway Route-Controlled Quantities of Radioactive Material

Thresholds for certain quantities of *radioactive* materials above which shipments are subject to specific routing controls that apply to the highway carrier. These thresholds are defined by U.S. Department of Transportation regulations (49 CFR Part 177). (49 CFR Part 397 Subpart D defines routing requirements.)

horizon

See *repository horizon*.

human intrusion

The inadvertent disturbance of a *disposal* system by the activities of humans that could result in release of *radioactive* waste. 40 CFR Part 191 Subpart B requires that *performance assessments* consider the possibility of human intrusion.

hydrogeology

A study that encompasses the interrelationships of *geologic* materials and processes involving water.

hydrographic area

In reference to Nevada *groundwater*, divisions of the State into groundwater basins and sub-basins based primarily on topographic features such as mountains and valleys. The State uses the map of hydrographic areas as the basis for water planning, management, and administration. (Because they are based heavily on topographic features, hydrographic area boundaries sometimes differ from groundwater basin designations developed from studies of inferred or measured groundwater flow patterns.)

hydrology

(1) The study of water characteristics, especially the movement of water. (2) The study of water, involving aspects of geology, oceanography, and meteorology.

igneous

(1) A type of rock formed from a molten, or partially molten, material. (2) An activity related to the formation and movement of molten rock either in the *subsurface* (plutonic) or on the surface (volcanic).

impact

For an EIS, the positive or negative effect of an action (past, present, or future) on the natural *environment* (land use, air quality, water resources, geological resources, ecological resources, aesthetic and scenic resources) and the human environment (infrastructure, economics, social, and cultural).

impact limiters

Devices attached to rail and truck *shipping casks* that would help absorb impact energy in the event of a collision.

implementing alternative

An action or proposition by DOE necessary to implement the *Proposed Action* and to enable the estimation of the range of reasonably foreseeable *impacts* of that action or proposition.

- The implementing rail/intermodal alternatives for Nevada transportation are the five corridors for a new rail spur:
  - Caliente
  - Carlin
  - Caliente-Chalk Mountain
  - Jean
  - Valley Modified

- The five *intermodal transfer station*/heavy-haul route combinations:
  - Caliente intermodal transfer station, Caliente route
  - Caliente intermodal transfer station, Caliente-Chalk Mountain route
  - Caliente intermodal transfer station, Caliente-Las Vegas route
  - Sloan/Jean intermodal transfer station, Sloan/Jean route
  - Apex/Dry Lake intermodal transfer station, Apex/Dry Lake route

DOE decisions on implementing alternatives will be made when they are ripe for decisionmaking, which might occur after a decision to construct and operate the Yucca Mountain Repository.

inadvertent intrusion

The unintended disturbance of a *disposal* facility or its immediate *environment* by a future occupant that could result in a loss of *containment* of the waste or *exposure* of people.

incident-free transportation

Routine transportation in which cargo travels from origin to destination without being involved in an *accident*.

indirect impact

An effect that is related to but removed from a proposed action by an intermediate step or process. Examples include surface-water quality changes resulting from soil erosion at construction sites, and reductions in productivity resulting from changes in soil temperature.

industrial wastewater

Liquid wastes from industrial processes that do not include sanitary sewage. Repository industrial wastewater would include water used for dust suppression and process water from building heating, ventilation, and air conditioning systems.

inert

Lacking active thermal, chemical, or biological properties. An inert atmosphere is incapable of supporting combustion.

infiltration

The process of water entering the soil at the ground surface and the ensuing movement downward. Infiltration becomes *percolation* when water has moved below the depth at which it can return to the atmosphere by evaporation or *evapotranspiration*.

infrastructure

Basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communication systems. These include surface and *subsurface* facilities (for example, service drifts, transporters, electric power supplies, waste handling buildings, administrative facilities).

in situ

In its natural position or place. The phrase distinguishes in-place experiments, conducted in the field or underground facility, from those conducted in the laboratory.

institutional control

Monitoring and maintenance of storage facilities to ensure that radiological releases to the *environment* and *radiation* doses to workers and the public remain within Federal limits and DOE

Order requirements. *Active institutional control* would require the presence of humans to safeguard and maintain the site; passive institutional control would include such devices as permanent markers and land records to warn future generations of dangers.

intermodal transfer station

A facility at the juncture of rail and road transportation used to transfer *shipping casks* containing *spent nuclear fuel* and *high-level radioactive waste* from rail to truck and empty casks from truck to rail.

intermodal transfer station candidate area

Area near one or more existing main rail lines that DOE is considering for the location of an *intermodal transfer station*.

intrablock fault

A relatively minor fault that lies between the major north-trending, block-bounding faults. Also called subsidiary fault.

intrusive sound

A new sound that, either because of its loudness in relation to the local *ambient* sound level, or because of such characteristics as tone content, impulsive or unexpected nature, or high information content, is annoying or detracts from the usual ambiance of the receptor location. See *noise*.

invasive species

An *alien species* whose introduction does or is likely to cause economic or environmental harm or harm to human health.

invert

The structure constructed in a *drift* to provide the floor of that drift. In an *emplacement* drift, ballast in the invert would serve as a *barrier* to migration of *radionuclides* that escaped from breached *waste packages*.

involved worker

A worker who would be directly involved in the activities related to facility construction and operations, including excavation activities; receipt, handling, packaging, and *emplacement* of waste materials; and *monitoring* of the condition and performance of the *waste packages*. See *noninvolved worker*.

ion

(1) An atom that contains excess *electrons* or is deficient in electrons, causing it to be chemically active. (2) An electron not associated with a *nucleus*.

ionizing radiation

(1) *Alpha particles*, *beta particles*, *gamma rays*, *X-rays*, *neutrons*, high-speed *electrons*, high-speed *protons*, and other particles capable of producing *ions*. (2) Any radiation capable of displacing electrons from an atom or molecule, thereby producing ions.

irradiation

Exposure to *radiation*.

isolation

Inhibiting the transport of *radioactive* material so that the amounts and concentrations of this material entering the *accessible environment* stay within prescribed limits.

isotope

One of two or more atomic *nuclei* with the same number of *protons* (that is, the same *atomic number*) but with a different number of *neutrons* (that is, a different *atomic weight*). For example, uranium-235 and uranium-238 are both isotopes of uranium.

Jackass Flats

A broad asymmetric basin 8 to 10 kilometers (5 to 6 miles) wide and 20 kilometers (12 miles) long that is east of Yucca Mountain and is drained by *Fortymile Wash*.

juvenile failure

Premature failure of a *waste package* because of material imperfections or damage by rockfall during *emplacement*.

land withdrawal area

An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Las Vegas Valley shear zone

A major right-lateral strike-slip zone of faulting.

latent cancer fatality

A death resulting from *cancer* that has been caused by exposure to *ionizing radiation*. For exposures that result in cancers, the generally accepted assumption is that there is a latent period between the time an exposure occurs and the time a cancer becomes active.

legal-weight truck

A truck with a gross vehicle weight (both truck and cargo weight) of less than 36,300 kilograms (80,000 pounds), the loaded weight limit for commercial vehicles operated on public highways without special state-issued permits. In addition, the dimensions, axle spacing, and, if applicable, axle loads of these vehicles must be within Federal and state regulations.

License Application

An application to the Nuclear Regulatory Commission to construct a *geologic repository* for the disposal of *spent nuclear fuel* and *high-level radioactive waste*. The application would be considered by the Nuclear Regulatory Commission in any decision whether to grant DOE authorization to begin constructing a repository.

line-loading repository design

A waste *emplacement* design in which *waste packages* would be spaced closely enough along the axis of the *drift* such that the heat source could be assumed to be continuous in long-term performance analyses.

linear thermal load

Heat output per unit length of the emplacement *drift*; expressed in kilowatts per meter.

lithology

The study and description of the general, gross physical characteristics of a rock, especially sedimentary *clastics*, including color, grain size, and composition.

lost workday cases

Incidents that result in injuries that cause the loss of work time.

lower-temperature repository operating mode

The *flexible design* would have the ability to hold repository host rock temperatures below the boiling point of water [96°C (205°F) at the elevation of the repository] after closure by a combination of methods such as increasing the continuous ventilation period, aging the fuel prior to *emplacement*, and increasing the spacing between emplaced waste packages. The mode ranges include conditions under which the drift rock wall temperatures would be below the boiling point of water, and conditions under which the waste package surface temperature would not exceed 85ºC (185ºF). To bound the impact analysis, DOE considered conditions under which the rock wall temperatures would be above the boiling point of water, and conditions under which waste package surface temperatures would not exceed 85ºC. See *higher-temperature repository operating mode*.

low-income population

One in which 20 percent or more of the persons in the population live in poverty, as reported by the Bureau of the Census in accordance with Office of Management and Budget requirements.

low-level radioactive waste

Radioactive waste that is not classified as *high-level radioactive waste*, *transuranic waste*, or byproduct tailings containing uranium or thorium from processed ore. Usually generated by hospitals, research laboratories, and certain industries.

maintenance

Activities during the repository operation and monitoring phase including maintenance of *subsurface* monitoring and instrumentation systems and utilities (compressed air, water supply, fire water, wastewater system, power supply, and lights), maintenance of the main ventilation fan installations and surface facilities related to underground activities, and site security. Maintenance also preserves the capability to retrieve emplaced *waste packages*. See *repository phases*.

matrix (geology)

The solid, but porous, portion of rock.

maximally exposed individual

A hypothetical individual whose location and habits result in the highest total radiological or chemical exposure (and thus *dose*) from a particular source for all exposure routes (for example, inhalation, ingestion, direct exposure). The EIS analyses used the concept of the maximally exposed individual to evaluate potential short-term impacts to individuals around the repository and from transportation (and for some aspects of the *No-Action Alternative*). The EIS analyses used the concept of the maximally exposed individual to evaluate potential short-term impacts to individuals around the repository and from transportation (and for some aspects of the No-Action Alternative. For potential impacts to individuals from long-term repository performance, see *receptor*.

Maximum Contaminant Level

Under the Safe Drinking Water Act, the maximum permissible concentrations of specific constituents in drinking water that is delivered to any user of a public water system that serves 15 or more connections and 25 or more people; the standards established as maximum contaminant levels consider the feasibility and cost of attaining the standard.

maximum reasonably foreseeable accident

An accident characterized by extremes of mechanical (impact) forces, heat (fire), and other conditions that would lead to the highest foreseeable consequences. In general, accidents with conditions that have a chance of occurring more often than 1 in 10 million in a year are considered to be reasonably foreseeable.

metamorphic

Rock in which the original mineralogy, texture, or composition has changed due to the effects of pressure, temperature, or the gain or loss of chemical components.

metric tons of heavy metal (MTHM)

Quantities of *spent nuclear fuel* without the inclusion of other materials such as *cladding* (the tubes containing the fuel) and structural materials. A metric ton is 1,000 kilograms (1.1 tons or 2,200 pounds). Uranium and other metals in spent nuclear fuel (such as thorium and plutonium) are called *heavy metals* because they are extremely dense; that is, they have high weights per unit volume.

millirad

One one-thousandth (0.001) of a *rad*.

millirem

One one-thousandth (0.001) of a *rem*.

minority population

A community in which the percent of the population of a racial or ethnic minority is 10 points higher than the percent found in the population as a whole.

mitigation

Actions and decisions that (1) avoid *impacts* altogether by not taking a certain action or parts of an action, (2) minimize impacts by limiting the degree or magnitude of an action, (3) rectify the impact by repairing, rehabilitating, or restoring the *affected environment*, (4) reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action, or (5) compensate for an impact by replacing or providing substitute resources or *environments*.

mixed-oxide fuel

A mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors.

monitored geologic repository

A system, requiring licensing by the U.S. Nuclear Regulatory Commission, intended or used for the permanent underground *disposal* of *radioactive* waste (including *spent nuclear fuel*). A *geologic repository* includes (1) the geologic repository operations area, and (2) the geologic setting in the *controlled area* that provides *isolation* of the radioactive waste. The repository would be monitored between *emplacement* of the last *waste package* and closure.

monitoring

Activities during the repository operation and monitoring phase including the surveillance and testing of *waste packages* and the repository for *performance confirmation*. See *repository phases*.

National Environmental Policy Act, as amended (NEPA; 42 U.S.C. 4321 *et seq.*)

The Federal statute that is the national charter for protection of the *environment*. The Act is implemented by procedures issued by the Council on Environmental Quality and DOE.

native species

With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.

natural barrier

The physical components of the geologic *environment* that individually and collectively act to limit the movement of water or radionuclides. See *barrier*.

natural system

A host rock suitable for repository construction and waste *emplacement* and the surrounding rock formations. It includes *natural barriers* that provide *containment* and *isolation* by limiting radionuclide transport through the geohydrologic *environment* to the *biosphere* and provide conditions that will minimize the potential for *human intrusion* in the future.

natural ventilation

Ventilation driven by a difference in density between the air columns in connected *shafts* or ramps. The density difference is generally caused by a difference in air temperature between the shafts, which results in a pressure differential that induces the air flow. This phenomenon, which is common in underground mines, can be enhanced by differences in elevation between the intake and exhaust locations. In relation to this EIS, the repository would be unique in that, due to the heat output of the emplaced waste, the exhaust air temperature would virtually always be higher than the intake temperature. The heat supplied by the waste and the difference in elevation between the intake and exhaust shaft portals would mean that there would always be a pressure differential, and that it would always be positive (that is, it would induce flow from the intakes to the exhausts).

naval spent nuclear fuel

Spent nuclear fuel discharged from reactors in surface ships, submarines, and training reactors operated by the U.S. Navy.

near-field

The area of and conditions in the repository including the *drifts* and *waste packages* and the rock immediately surrounding the drifts. The region around the repository where the natural hydrogeologic system would be significantly impacted by the excavation of the repository and the *emplacement* of waste.

neutron

An atomic particle with no charge and an atomic mass of 1; a component of all atoms except hydrogen; frequently released as *radiation*.

neutron absorber

A material (such as boron or gadolinium) that absorbs neutrons. Used in *nuclear reactors*, transportation *casks*, and *waste packages* to control neutron activity and prevent criticality.

nitrogen oxides

Gases formed in great part from atmospheric nitrogen and oxygen when combustion occurs under conditions of high temperature and high pressure; a major air pollutant. Two primary nitrogen oxides, nitric oxide (NO) and nitrogen dioxide (NO_2), are important airborne *contaminants*. Nitric oxide combines with atmospheric oxygen to produce nitrogen dioxide. Both nitric oxide and nitrogen dioxide can, in high concentration, cause lung cancer. Nitrogen dioxide is a *criteria pollutant*.

No-Action Alternative

The *Nuclear Waste Policy Act* states that this EIS does not have to discuss *alternatives* to geologic disposal or alternative sites to Yucca Mountain; DOE included the analysis of the No-Action Alternative to provide a basis for comparison with the *Proposed Action*. For this EIS, under the No-Action Alternative DOE would end *site characterization* activities at Yucca Mountain and continue to accumulate *spent nuclear fuel* and *high-level radioactive waste* at commercial storage sites and DOE facilities. See *alternative*.

noble gas

Any of a group of rare gases that include helium, neon, argon, krypton, xenon, and radon and that exhibit great chemical stability and extremely low reaction rates; also called *inert* gas. Xenon and radon exhibit extremely low reaction rates.

noise

Any sound that is undesirable because it interferes with speech and hearing; if intense enough, it can damage hearing.

nominal scenario

Long-term performance of the proposed repository using the Proposed Action modeled inventory, undisturbed by volcanic activity or human intrusion, but including seismic activity.

nonattainment area

An area that does not meet the *ambient air quality standard* for one or more criteria pollutants. Further designations (for example, serious, moderate) describe the magnitude of the nonattainment.

noninvolved worker

A worker who would perform managerial, technical, supervisory, or administrative activities but would not be directly involved in construction, excavation, or operations activities. See *involved worker*.

normal distribution

As used in analyses of long-term performance, a special type of symmetrical distribution known in the science of statistics as the Gaussian Distribution and commonly known as the “bell-shaped curve.” *See distribution.*

normal fault

A fault in which the relative displacement is along the direction of dip of the fault plane (*dip-slip fault*) where the block above the fault has moved downward in relation to the block below the fault. See *reverse fault*.

nuclear radiation

Radiation that emanates from an unstable atomic *nucleus*.

nuclear reactor

A device in which a nuclear *fission chain reaction* can be initiated, sustained, and controlled to generate heat or to produce useful radiation.

nuclear waste

Unusable by-products of nuclear power generation, nuclear weapons production, and research, including *spent nuclear fuel, high-level radioactive waste*.

Nuclear Waste Policy Act (NWPA; 42 U.S.C. 10101 *et seq.*)

The Federal statute, originally enacted in 1982 (Public Law 97-425; 96 Stat. 2201), that established the Office of Civilian Radioactive Waste Management and defines its mission to develop a Federal system for the management and geologic disposal of *commercial spent nuclear fuel* and other *high-level radioactive wastes*, as appropriate. The Act also specifies other Federal responsibilities for nuclear waste management, establishes the Nuclear Waste Fund to cover the cost of geologic *disposal*, authorizes interim storage under certain circumstances, and defines interactions between Federal agencies and the states, local governments, and Native American tribes. The Act was substantially amended in 1987 (see *Nuclear Waste Policy Act Amendments of 1987*) and 1992 (see *Energy Policy Act of 1992*).

Nuclear Waste Policy Act Amendments of 1987 (Public Law 100-203; 101 Stat. 1330)

Legislation that amended the *Nuclear Waste Policy Act* to limit repository *site characterization* activities to Yucca Mountain, Nevada; establish the Office of Nuclear Waste Negotiator to seek a state or Native American tribe willing to host a repository or monitored retrievable storage facility; create the *Nuclear Waste Technical Review Board*; and increase state and local government participation in the waste management program.

Nuclear Waste Technical Review Board

An independent body established within the executive branch, created by the *Nuclear Waste Policy Amendments Act of 1987* to evaluate the technical and scientific validity of activities undertaken by the U.S. Department of Energy, including *site characterization* activities and activities relating to the packaging or transportation of *high-level radioactive waste* or *spent nuclear fuel*. Members of this Board are appointed by the President from a list prepared by the National Academy of Sciences.

nucleus

The central, positively charged, dense portion of an atom. Also known as atomic nucleus.

nuclide

An atomic *nucleus* specified by its *atomic weight*, *atomic number*, and energy state; a radionuclide is a *radioactive* nuclide.

oblique-slip fault

A *fault* that combines some purely horizontal motion (*strike-slip fault*) with some along the direction of the dip of the fault plane (*dip-slip fault*).

offsite

Physically not in a repository-related area managed by DOE.

onsite

Physically in an area managed by DOE where access can be limited for any reason. The site boundary encompasses *controlled areas*. The site comprises the various Operations Areas and the areas between and immediately surrounding them.

operational storage

A storage capacity DOE could use to collect material shipped to the repository before (or after) its insertion in *waste packages* and *emplacement* in the repository.

operation and monitoring

See *repository phases*.

option

As used in the transportation analysis in this EIS, a variation based on a determination that the location of a rail *corridor* segment is essentially equivalent to that of another option considering environmental and engineering factors. See *variation*, *alternate*, *corridor*.

organism

An individual constituted to carry on the activities of life by means of organs separate but mutually dependent; a living being.

overburden

Geologic material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials. As used by the Yucca Mountain Project, this is geologic material overlying the *repository block*.

overweight, overdimension truck

Semi- and tandem tractor-trailer trucks with gross weights over 80,000 pounds that must obtain permits from state highway authorities to use public highways.

ozone (O_3)

The triatomic form of oxygen; in the *stratosphere*, ozone protects the Earth from the Sun's *ultraviolet radiation*, but in lower levels of the atmosphere it is an air pollutant.

Paleozoic Era

A geologic era extending from the end of the Precambrian to the beginning of the Mesozoic, dating from about 600 to 230 million years ago.

particulate matter

Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog, found in air or emissions. See PM_{10}.

pathway

A potential route by which radionuclides might reach the *accessible environment* and pose a threat to humans.

peak of the mean annual dose (post-10,000 years)

For this EIS, the maximum of the mean annual *dose* analyzed for the 1-million-year postclosure period. Because the dose would decline after this peak, this would be the peak for all time after closure. See *10,000-year peak of the mean annual dose*.

pediment

A planar sloping rock surface forming a ramp to a front of a mountain range in an arid region. It might be covered locally by a thin *alluvium*.

perched water

A *saturated zone* condition that is not continuous with the *water table*, because there is an impervious or semipervious layer underlying the perched zone or a *fault* zone that creates a *barrier* to water movement and perches water. See *permeable.*

percolation

The passage of a liquid through a porous substance. In rock or soil it is the movement of water through the interstices and pores under hydrostatic pressure and the influence of gravity. The downward or lateral flow of water that becomes net *infiltration* in the *unsaturated zone*.

perennial yield

The amount of usable water from a *groundwater* aquifer that can be economically withdrawn and consumed each year for an indefinite period. It cannot exceed the natural recharge to that aquifer and ultimately is limited to the maximum amount of discharge that can be used for beneficial use.

performance assessment

An analysis that estimates the potential behavior of a system or system component under a given set of conditions. Performance assessments include estimates of the effects of *uncertainties* in data and modeling. See *Total System Performance Assessment.*

performance confirmation

The program of tests, experiments, and analyses conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after *permanent closure* will be met.

permanent closure

Final sealing of *shafts* and *boreholes* of the underground facility, including the installation of permanent monuments to mark the location and boundaries of the repository.

permeable

Pervious; a permeable rock is a rock, either porous or cracked, that allows water to soak into and pass through it freely.

permeability

In general terms, the capacity of such mediums as rock, sediment, and soil to transmit liquid or gas. Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they interconnect. "Hydraulic conductivity" is equivalent to "permeability" in technical discussions relating to *groundwater*.

person-rem
: A unit used to measure the *radiation* exposure to an entire group and to compare the effects of different amounts of radiation on groups of people; it is the product of the average *dose equivalent* (in *rem*) to a given organ or tissue multiplied by the number of persons in the population of interest.

pH
: A number indicating the acidity or alkalinity of a solution. A pH of 7 indicates a neutral solution. Lower pH values indicate more acidic solutions while higher pH values indicate alkaline solutions.

photon
: A massless particle, the quantum of an electromagnetic field, carrying energy, momentum, and angular momentum.

photovoltaic
: Capable of generating a voltage as a result of exposure to *radiation*. Solar power generation systems use photovoltaic energy from the sun's radiation to produce electricity.

picocurie
: One one-trillionth (1×10^{-12}) of a *curie*.

pillar
: The rock section between adjacent *emplacement drifts*.

PM_{10}
: All *particulate matter* in the air with an aerodynamic diameter less than or equal to a nominal 10 micrometers (0.0004 inch). Particles less than this diameter are small enough to be breathable and could be deposited in lungs.

polycyclic volcanism
: Multiple cycles of volcanic activity, as in describing a cinder cone that resulted from numerous volcanic events separated by significant intervals of time (as opposed to a cone generated by a single event or a tightly grouped series of events).

population dose
: A summation of the radiation doses received by individuals in an exposed population; equivalent to *collective dose*; expressed in *person-rem*.

portal
: Surface entrance to a mine, particularly in a *drift* or tunnel. The North and South Portals are the two primary entrances to the *subsurface* facilities.

postclosure controlled area
: See *controlled area*.

preferred route

A public highway route that satisfies the requirements of U.S. Department of Transportation regulations (49 CFR Part 397, Subpart D) to be acceptable for shipments of *Highway Route-Controlled Quantities of Radioactive Material*.

pressurized-water reactor (PWR)

A nuclear power *reactor* that uses water under pressure as a coolant. The water boiled to generate steam is in a separate system.

prime farmland

Land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion.

probabilistic

(1) Based on or subject to *probability*. (2) Involving a variable factor, such as temperature or porosity. At each instance of time, the factor may take on any of the values of a specified set with a certain probability. Data from a probabilistic process is an ordered set of observations, each of which is one item in a probability distribution.

probability

The relative frequency at which an event can occur in a defined period. Statistical probability is about what actually happens in the real world and can be verified by observation or sampling. Knowing the exact probability of an event is usually limited by the inability to know, or compile the complete set of, all possible outcomes over time or space. Probability is measured on a scale of 0 (event will *not* occur) to 1 (event *will* occur).

probable maximum flood

The hypothetical flood (peak discharge, volume, and hydrographic shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of probable maximum precipitation and other hydrologic factors, such as sequential storms and snowmelts, that are favorable for maximum flood runoff.

proposed action

The activity proposed to accomplish a Federal agency's purpose and need. An EIS analyzes the environmental *impacts* of the Proposed Action. A proposed action includes the project and its related support activities (preconstruction, construction, and operation, along with postoperational requirements). The Proposed Action in this EIS is the construction, operation and monitoring, and eventual closure of a *monitored geologic repository* for *spent nuclear fuel* and *high-level radioactive waste* at Yucca Mountain in Nevada (see *repository phases*).

proton

An elementary particle that is the positively charged component of ordinary matter and, together with the *neutron*, is a building block of all atomic *nuclei*.

pyroclastic

Of or relating to individual particles or fragments of *clastic* rock material of any size formed by volcanic explosion or ejected from a volcanic vent.

qualitative
: With regard to a variable, a parameter, or data, an expression or description of an aspect in terms of non-numeric qualities or attributes. See *quantitative*.

quantitative
: A numeric expression of a variable. See *qualitative.*

rad
: The unit of measure of absorbed *radiation* dose in terms of energy. One rad is equal to an absorbed *dose* of 100 ergs per gram. (In the metric system of measurements, an erg is a unit of energy. One foot-pound is equal to 13,560,000 ergs.)

radiation
: The emitted particles or *photons* from the *nuclei* of *radioactive* atoms. Some elements are naturally radioactive; others are induced to become radioactive by *irradiation* in a *reactor*. Naturally occurring radiation is indistinguishable from induced radiation.

radioactive
: Emitting *radioactivity*.

radioactive decay
: The process in which one *radionuclide* spontaneously transforms into one or more different radionuclides, which are called decay products.

radioactivity
: The property possessed by some elements (for example, uranium) of spontaneously emitting alpha, beta, or *gamma rays* by the *disintegration* of atomic *nuclei*.

radiologically controlled area
: An area of the surface repository enclosed by security fences, control gates, lighting, and detection systems established to prevent the spread of radiological contamination. The area would include the facilities and transportation systems required to receive and ship rail and truck waste shipments, prepare *shipping casks* for handling, and load *waste forms* into disposal containers for *emplacement* in the repository. It would also include the facility and systems required to treat and package site-generated *low-level radioactive waste* for offsite disposal.

radionuclide
: See *nuclide*.

rail classification yard
: A railroad switching yard where railcars arriving in inbound freight trains are classified and reassembled according to their routing to make up outbound freight trains.

rail route
: Route from point of origin to the repository.

reactor
: See *nuclear reactor*.

release fraction

The fraction of each *isotope* in *spent nuclear fuel* or *high-level radioactive waste* that could be released from a containment in an *accident*.

real disposable income

The dollar income, including the value of transfer payments, available to individuals after taxes have been paid; also referred to as *real disposable personal income*.

reasonably maximally exposed individual

See *receptor*.

receptor

A hypothetical person who is exposed to environmental contaminants (in this case *radionuclides*) in such a way—by a combination of factors including location, lifestyle, dietary habits, etc.—that this individual is representative of the *exposure* of the general population. DOE used this hypothetical individual to evaluate long-term repository performance. The receptor represents the "Reasonably Maximally Exposed Individual (RMEI)" defined in 40 CFR Part 197. The Draft EIS defined the receptor slightly differently and called this hypothetical person the *maximally exposed individual,* which is still used for evaluating short-term impacts.

recharge

The movement of water from an *unsaturated zone* to a *saturated zone*.

recordable cases

Occupational injuries or occupation-related illnesses that result in (1) a fatality, regardless of the time between the injury or the onset of the illness and death, (2) lost workday cases (nonfatal), and (3) the transfer of a worker to another job, termination of employment, medical treatment, loss of consciousness, or restriction of motion during work activities.

Record of Decision

A document that provides a concise public record of a decision made by a government agency.

region of influence

The physical area that bounds the environmental, sociologic, economic, or cultural features of interest for the purpose of analysis.

rem

A unit of *dose equivalent.*

remediation

Action taken to permanently remedy a release or threatened release of a hazardous substance to the *environment*, instead of or in addition to removal.

repository

See *geologic repository*.

repository block

The portion of rock in Yucca Mountain that would house the repository, if the site was suitable.

repository horizon

The area within the *repository block* where *emplacement drifts* would be excavated. Also called emplacement horizon.

repository phases

The development of a monitored geologic repository at Yucca Mountain, if approved, would have three phases, as follows:

- *Construction:* Activities during this phase would include preparing the site, constructing surface waste handling and support facilities, excavating and equipping a portion of the repository *subsurface* for initial waste *emplacement*, and conducting initial verification testing of components and systems.

- *Operation and monitoring:* Repository operations activities would include waste receipt, repackaging, and emplacement in the repository; continuing subsurface development for waste *emplacement; monitoring; and maintenance*. Monitoring would begin with the initial emplacement of waste in the repository and would end at repository closure. In addition, the maintenance of repository facilities would continue until the closure of the repository. See *monitoring*, *maintenance*.

- *Closure:* The closure of the *subsurface* repository facilities would include the removal and salvage of equipment and materials; filling of the main *drifts*, access ramps, and ventilation shafts; and sealing of openings, including ventilation shafts, access ramps, and *boreholes*. Surface closure activities would include the construction of monuments to mark the repository location, *decommissioning* and demolition of facilities, and restoration of the site to its approximate condition before the construction of the repository facilities.

respirable fraction

The fraction of *aerosol* released in an *accident* that consists of particles or droplets having aerodynamic effective diameters of 10 microns (about 4 millionths of an inch) or less.

retrieval

The act of removing *radioactive* waste from the underground location at which the waste had been previously emplaced for disposal. Retrieval would be a contingency action, performed only if *monitoring* indicated that the waste needed to be retrieved in order to protect the public health and safety or the environment or to recover resources from *spent nuclear fuel*.

reverse fault

A *fault* in which the relative displacement is along the direction of the dip of the fault plane (*dip-slip fault*), and in which the block above the fault has moved upward in relation to the block below the fault.

riparian

Of, on, or pertaining to the bank of a river or stream, or of a pond or small lake.

riprap

Broken stones or chunks of concrete used as foundation material or in embankments to control water flow or prevent erosion.

risk

The product of the probability that an undesirable event will occur multiplied by the consequences of the undesirable event.

safe haven

Designated safe parking locations along transportation routes.

sanitary and industrial solid waste

Solid waste that is neither hazardous nor radioactive. Sanitary waste streams include paper, glass, and discarded office material. State of Nevada waste regulations identify this waste stream as household waste.

sanitary waste

Domestic wastewater from toilets, sinks, showers, kitchens, and floor drains from restrooms, change rooms, and food preparation and storage areas.

saturated zone

The area below the *water table* where all spaces (*fractures* and rock pores) are completely filled with water.

scenario

A specific set of actions, activities, and assumptions. Scenarios are identified and analyzed to enable the estimation of the range of environmental impacts associated with the *Proposed Action* and the *No-Action Alternative*. The environmental impacts identified from these scenarios provide environmental information to support Departmental decisions about the *alternatives* and *implementing alternatives*.

scoria

Bubbly, glassy lava rock of basaltic composition that originated as hot, welded materials ejected from a volcano. Small fragments are called “cinders.”

seismic

Pertaining to, characteristic of, or produced by *earthquakes* or earth vibrations.

seismicity

A seismic event or activity such as an *earthquake* or earth tremor; *seismic* action.

sensitive structures

Buildings or structures, usually old and of cultural value, or facilities that house vibration-sensitive equipment, that could be susceptible to ground vibrations, activities, or conditions causing *ground vibrations*.

shaft

For the Yucca Mountain Repository, an excavation or vertical passage of limited area, compared to its depth, used to ventilate underground facilities.

shielding

Any material that provides *radiation* protection.

shipment

The movement of a properly prepared (loaded, unloaded, or empty) *cask* from one site to another and associated activities to ensure compliance with applicable regulations.

shipping cask

A heavily shielded massive container that meets regulatory requirements for shipping *spent nuclear fuel* or *high-level radioactive waste*. See *cask*.

single-purpose (storage or transportation) cask

A heavily shielded massive container for the dry storage of *spent nuclear fuel*; it is usable for either storage or transportation but not for *emplacement* in a repository. See *cask*.

site boundary

The boundary of the land withdrawal area used for analytical purposes in this EIS. See *land withdrawal area*.

site characterization

Activities associated with the determination of the suitability of the Yucca Mountain site as a *monitored geologic repository*. DOE constructed the *Exploratory Studies Facility* to support the following activities related to the determination of site suitability, including surface facilities and *subsurface* ramps and *drifts*:

- Gather and evaluate surface and subsurface site data
- Predict the performance of the repository
- Prepare the repository design
- Assess the performance of the system against the required Code of Federal Regulations and program performance criteria

Some of the exploratory surface and subsurface facilities would be enhanced during the repository construction phase (see *repository phases*); others would be removed, demolished, or relocated, as necessary. Data gathering associated with site characterization would end with any Site Recommendation decision.

site-generated waste

Waste or wastewater generated at the *monitored geologic repository* and related transportation facilities.

Site Recommendation

A recommendation by the Secretary of Energy to the President that the Yucca Mountain site be approved for development as the Nation's first *spent nuclear fuel* and *high-level radioactive waste* repository.

soil recovery

The return of disturbed land to a relatively stable condition with a form and productivity similar to that which existed before any disturbance.

sound barrier
Natural or artificial structures that block or interfere with the propagation of sound; examples include terrain features and manmade structures (buildings, walls, etc.).

source term
Types and amounts of radionuclides that are the source of a potential release of *radioactivity*.

Spaghetti Bowl
As used in this EIS, the intersection of Interstate Highway 15 and U.S. Highway 93/95 in Las Vegas, Nevada.

spalling
(1) Flaking off of corrosion products from the metal *substrate* as it undergoes corrosion. The layer of corroded material thickens. The spalling could be caused by an expansive action of the corrosion products because they occupy a greater volume than the uncorroded metal substrate. (2) Flaking, chipping, or cracking at the opening of a *borehole*, *shaft*, or other rock excavation.

Special-Performance-Assessment-Required (SPAR) wastes
Low-level radioactive wastes generated in DOE production reactors, research reactors, reprocessing facilities, and research and development activities that exceed the Nuclear Regulatory Commission Class C shallow-land burial disposal limits.

spent nuclear fuel
Fuel that has been withdrawn from a *nuclear reactor* following *irradiation*, the component elements of which have not been separated by reprocessing. For this project, this refers to (1) intact, nondefective *fuel assemblies*, (2) failed fuel assemblies in canisters, (3) fuel assemblies in canisters, (4) consolidated fuel rods in canisters, (5) nonfuel assembly hardware inserted in *pressurized-water reactor* fuel assemblies, (6) fuel channels attached to *boiling-water reactor* fuel assemblies, and (7) nonfuel assembly hardware and structural parts of assemblies resulting from consolidation in *canisters*.

spoils areas
Areas outside the rail corridor for the deposition of excavated materials from rail line development.

stakeholder
A person or organization with an interest in or affected by DOE actions (representatives from Federal, state, tribal, or local agencies; members of Congress or state legislatures; unions, educational groups, environmental groups, industrial groups, etc.; and members of the general public).

storage
The collection and containment of waste or *spent nuclear fuel* in a way that does not constitute *disposal* of the waste or *spent nuclear fuel* for the purposes of awaiting treatment or disposal capacity.

storage cask
See *cask*.

storage container

See *cask*.

stratigraphy

The branch of geology that deals with the definition and interpretation of rock strata, the conditions of their formation, character, arrangement, sequence, age, distribution, and especially their correlation by the use of fossils and other means of identification. See *stratum*.

stratosphere

The atmospheric shell above the troposphere and below the mesosphere. It extends from 10 to 20 kilometers (6 to 12 miles) to about 53 kilometers (33 miles) above the surface.

stratum

A sheetlike mass of sedimentary rock or earth of one kind lying between beds of other kinds.

strike-slip fault

A fault with purely horizontal relative displacement.

subcritical

Having an effective multiplication constant less than 1, so that a self-supporting *chain reaction* cannot be maintained in a *nuclear reactor*.

subsidiary fault

See *intrablock fault*.

substrate

Basic surface on which a material adheres.

subsurface

A zone below the surface of the Earth, the *geologic* features of which are principally layers of rock that have been tilted or faulted and are interpreted on the basis of drill hole records and geophysical (*seismic* or rock vibration) evidence. In general, it is all rock and solid materials lying beneath the Earth's surface.

sulfur dioxide

A pungent, colorless gas produced during the burning of sulfur-containing fossil fuels. It is the main pollutant involved in the formation of acid rain. Coal- and oil-burning electric utilities are the major source of sulfur dioxide in the United States. Inhaled sulfur dioxide can damage the human respiratory tract and can severely damage vegetation. See *criteria pollutants*, *ambient air quality standards*.

sulfur oxides

A mixture of sulfur dioxide, sulfur trioxide, and inorganic sulfites and sulfates. Sulfur dioxide combines with oxygen in the air to form sulfur trioxide and microscopic aerosol sulfite and sulfate particles, all of which are lung irritants. See *criteria pollutants*, *ambient air quality standards.*

supernate
A concentrated form of *radioactive* waste that floats to the top of an undisturbed container of liquid *high-level radioactive waste*.

thermal loading
(1) The spatial density at which *waste packages* would be emplaced within the repository as characterized by the areal power density and the *areal mass loading*. (2) The application of heat to a system, usually measured in terms of watts per unit area. The thermal load for a repository would be the watts per acre produced by the *radioactive* waste in the active disposal area.

thermal shunt
A metal structure, usually aluminum, that would be added to *waste packages* as needed to greatly improve heat conduction between the center of the waste package and the outer edge, thereby providing a reliable means to keep the temperature of the *cladding* within design limits.

threatened species
A species that is likely to become an *endangered species* within the foreseeable future throughout all or a significant part of its range.

thrust fault
A *reverse fault* in which the angle of the fault plane is less than 45 degrees.

total employment
The sum of direct and indirect employment resulting from initiation of an activity. Direct employment consists of jobs performing the activity. Indirect employment consists of jobs in other activities supporting the direct employees. Also defined as composite employment.

total population
The sum of all people associated with direct and indirect employees and their families resulting from initiation of an activity.

Total System Performance Assessment
A risk assessment that quantitatively estimates how the proposed Yucca Mountain Repository system could perform under the influence of specific features, events, and processes, incorporating *uncertainty* in the models and data. See *performance assessment*.

toxic air pollutants
Hazardous pollutants not listed as either *criteria pollutants* or *hazardous pollutants*.

traditional cultural property
A property that is eligible for inclusion in the National Register of Historic Places because of its association with cultural practices or beliefs of a living community that are rooted in that community's history, and are important in maintaining the continuing cultural identity of the community. Culture includes the traditions, beliefs, practices, lifeways, arts, crafts, and social institutions of any community, be it a Native American tribe, a local ethnic group, or the people of the Nation as a whole. Properties can include buildings, structures, and sites; groups of buildings, structures, or sites forming historic districts; and individual objects.

transpiration

The process by which water enters a plant through its root system, passes through its vascular system, and is released into the atmosphere through openings in its outer covering. It is an important process for removal of water that has infiltrated below the zone where it could be removed by evaporation.

transuranic waste

Waste materials (excluding *high-level radioactive waste* and certain other waste types) contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and that occur in concentrations greater than 100 nanocuries per gram. Transuranic waste results primarily from treating and fabricating plutonium as well as research activities at DOE defense installations.

trunnion

A projection from a vessel or other piece of equipment that facilitates attachment to a lifting device.

tuff

Igneous rock formed from compacted volcanic fragments from *pyroclastic* (explosively ejected) flows with particles generally smaller than 4 millimeters (about 0.16 inch) in diameter—the most abundant type of rock at the Yucca Mountain site. Nonwelded tuff results when volcanic ash cools in the air sufficiently that it doesn't melt together, yet later becomes rock through compression. See *welded tuff*.

ultraviolet radiation

Electromagnetic radiation with wavelengths from 4 to 400 nanometers. This range begins at the short wavelength limit of visible light and overlaps the wavelengths of long *x-rays* (some scientists place the lower limit at higher values, up to 40 nanometers). Also known as ultraviolet light.

uncanistered spent nuclear fuel

Commercial spent nuclear fuel placed directly into shipping casks. At the repository, *spent nuclear fuel* assemblies would be removed from the *shipping cask* in a *disposal container* or in the fuel pool to accomodate *blending*.

uncertainty

A measure of how much a calculated or estimated value that is used as a reasonable guess or prediction might vary from the unknown true value.

unique farmland

Land other than *prime farmland* that is used for the production of specific high-value food and fiber crops such as citrus, tree nuts, olives, cranberries, fruits, and vegetables.

unsaturated zone

The zone of soil or rock below the ground surface and above the *water table*.

vadose zone

See *unsaturated zone*.

variation
As used in the transportation analysis in this EIS, a strip of land, approximately 400 meters (0.25 mile) wide, from one point along a corridor to another point along the same corridor that describes a different route. See *alternate*, *option*, *corridor*.

Viability Assessment
An assessment of the prospects for geologic disposal at the Yucca Mountain site, based on repository and *waste package* design, a *Total System Performance Assessment*, a *License Application* plan, and repository cost and schedule estimates. DOE issued the *Viability Assessment of a Repository at Yucca Mountain* in December 1998.

vicinity (in relation to the Yucca Mountain Repository)
A general term used in nonspecific discussions in this EIS about the area around the Yucca Mountain site.

viewshed
A total field of vision or a vista. In particular, an area with visual boundaries seen from various points within the area.

vitrification
A waste treatment process that uses glass (for example, *borosilicate glass*) to encapsulate or immobilize *radioactive* wastes.

vitrophyre
A volcanic rock with large crystals embedded in a glassy, obsidian-like matrix.

waste form
A generic term that refers to the different types of *radioactive* wastes.

waste package
A sealed container containing waste that is ready for *emplacement*. The waste package would contain the *waste form* and any internal structures necessary for structural support, thermal control, or nuclear control.

water table
(1) The upper limit of the *saturated zone* (the portion of the ground wholly saturated with water). (2) The upper surface of a zone of saturation above which the majority of pore spaces and fractures are less than 100 percent saturated with water most of the time (*unsaturated zone*) and below which the opposite is true (saturated zone).

welded tuff
A *tuff* deposited under conditions where the particles making up the rock were heated sufficiently to cohere. In contrast to nonwelded tuff, welded tuff is denser, less porous, and more likely to be fractured (which increases *permeability*).

wetland
A shoreline or other area, such as a marsh or swamp, that is saturated with moisture, especially when thought of as the natural habitat of wildlife.

wet storage

Storage of *radioactive* material that uses water for cooling or *shielding*, such as a spent nuclear fuel storage pool.

worker year

2,000 hours of paid labor; a project requiring 1.5 worker years would take 3,000 hours to complete.

X-rays

Penetrating electromagnetic *radiation* having a wavelength much shorter than that of visible light. X-rays are identical to *gamma rays* but originate outside the *nucleus*, either when the inner orbital *electrons* of an excited atom return to their normal state or when a metal target is bombarded with high-speed electrons.

Yucca Mountain Repository EIS

See *environmental impact statement (EIS)*.

Yucca Mountain site (the site):

The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

zeolite

Any of a group of hydrated silicates of aluminum with alkali metals, commonly occurring as secondary minerals in cavities in basic volcanic rocks.

zirconium alloy

An alloy material containing the element zirconium that might have any of several compositions. It is used as a *cladding* material.

15. INDEX

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CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Concentration					
Kilograms/sq. meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/sq. meter
Milligrams/liter	1[a]	Parts/million	Parts/million	1[a]	Milligrams/liter
Micrograms/liter	1[a]	Parts/billion	Parts/billion	1[a]	Micrograms/liter
Micrograms/cu. meter	1[a]	Parts/trillion	Parts/trillion	1[a]	Micrograms/cu. meter
Density					
Grams/cu. cm	62.428	Pounds/cu. ft.	Pounds/cu. ft.	0.016018	Grams/cu. cm
Grams/cu. meter	0.0000624	Pounds/cu. ft.	Pounds/cu. ft.	16,025.6	Grams/cu. meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F – 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cu. meters/second	2118.9	Cu. feet/minute	Cu. feet/minute	0.00047195	Cu. meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.78533	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor
exa-	E	1,000,000,000,000,000,000 = 10^{18}
peta-	P	1,000,000,000,000,000 = 10^{15}
tera-	T	1,000,000,000,000 = 10^{12}
giga-	G	1,000,000,000 = 10^{9}
mega-	M	1,000,000 = 10^{6}
kilo-	k	1,000 = 10^{3}
deca-	D	10 = 10^{1}
deci-	d	0.1 = 10^{-1}
centi-	c	0.01 = 10^{-2}
milli-	m	0.001 = 10^{-3}
micro-	µ	0.000 001 = 10^{-6}
nano-	n	0.000 000 001 = 10^{-9}
pico-	p	0.000 000 000 001 = 10^{-12}