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FINAL
WASTE MANAGEMENT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
for
Managing Treatment, Storage, and Disposal of
Radioactive and Hazardous Waste

Volume III of V

Appendices A–D

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Appendix A

Public Comments to DOE's Proposed Revisions to the Scope of the WM PEIS

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

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Acronyms

The following is a list of acronyms used in this appendix.

BEMR	Baseline Environmental Management Report
CERCLA	Comprehensive Environmental Response; Compensation and Liability Act
DOE	U.S. Department of Energy
NEPA	National Environmental Policy Act
NOI	Notice of Intent
PEIS	programmatic environmental impact statement
WM	Waste Management

APPENDIX A
Public Comments to DOE's Proposed Revisions to the Scope of the WM PEIS

On June 27, 1989, twenty-two citizens' groups, led by the Natural Resources Defense Council, filed suit to compel the U.S. Department of Energy (DOE) to prepare a programmatic environmental impact statement (PEIS) on proposals for the cleanup and modernization of the nuclear weapons production complex. Consequently, on January 12, 1990, the Secretary of Energy decided to prepare two programmatic environmental impact statements, one on the modernization of the nuclear weapons complex and the other on the Five-year Environmental Restoration and Waste Management Plan. Accordingly, on October 22, 1990, DOE issued a Notice of Intent (NOI) (55 FR 42633) to prepare the Environmental Restoration (ER) and Waste Management (WM) Programmatic Environmental Impact Statement (see Attachment 1). In the NOI, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." The NOI identified two separate sets of alternatives to be evaluated, one for environmental restoration and one for waste management.

The public scoping period on the PEIS extended from October 22, 1990, to February 19, 1991. Beginning on December 3, 1990, the Department held 23 scoping meetings at various locations across the country to ensure adequate opportunity for participation by the public and other government agencies. During the public comment period, over 1,200 people provided approximately 7,000 comments, either by participating in the meetings or by submitting materials and letters. Most concerns were related to the public perception of the Department and to environmental, health, and safety issues.

To record the results of the public scoping meetings and to serve as a plan for preparing the PEIS, a Draft Implementation Plan was prepared and made publicly available on February 4, 1992 (57 FR 4193). The Draft Implementation Plan summarized the comments received during the public scoping meetings and identified those issues, as suggested by the comments, that would be considered in preparing the PEIS. A public comment period on the Draft Implementation Plan extended from February 4, 1992, until April 24, 1992. During this time, six regional public workshops were held.

The Final Implementation Plan was completed in January 1994 and made available to the public (59 FR 7990, February 17, 1994). It addressed comments received during the public scoping meetings and those received on the Draft Implementation Plan as well.

Subsequently, the Department attempted to meaningfully analyze the environmental restoration alternatives that it originally defined in the Final Implementation Plan but concluded, after considerable effort, that it would not be appropriate to make programmatic decisions regarding cleanup strategies that would be applicable to all of the Department's sites.

Accordingly, the Department announced on January 24, 1995 (60 FR 4607), an opportunity for public comment on its proposal to shift the focus and change the title of the PEIS (see Attachment 2). The proposed modification would eliminate the environmental restoration alternatives and modify the proposed action. On March 16, 1995, (60 FR 14275) in response to a request from the public, the Department announced an extension of the public comment period on the proposed scope to April 10, 1995 (see Attachment 3). In both announcements, the Department stated that the draft PEIS would contain an appendix summarizing comments received during the resulting public comment period.

On April 10, 1995, the Natural Resources Defense Council (NRDC) filed a public comment in response to the notices of opportunity on the proposed modification to the scope and title of the PEIS. The NRDC's comments were the only ones DOE received.

The NRDC's letter (see Attachment 4) referred to the prior litigation between the Natural Resources Defense Council and the Department of Energy and stated that the Department indicated that its cleanup and waste management activities constituted actions that fall within the meaning of the National Environmental Policy Act (NEPA) and are thus subject to review. The letter also stated that the Department, during the course of litigation, committed to preparing a PEIS that included environmental restoration.

The NRDC cited several issues that it believes warrant full analysis and public participation, including those pertaining to standards; the scope and pace of the cleanup program; land use restrictions in setting cleanup levels; inter- and intra-facility priorities in light of budget constraints; and public participation in the decision process for cleanup. Further, NRDC noted that as a matter of policy, the Department does not perform reviews under NEPA for actions taken pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The Department agrees that there are issues with regard to the cleanup program for which a national perspective and public discussion are appropriate. DOE is considering some enhanced public participation to obtain input on such national environmental restoration issues. The Department believes that there are suitable analytical tools and venues available other than the PEIS, to address the issues raised in the Council's letter. These are discussed below.

As the Department noted in the *Federal Register*, the fundamental reasoning behind its decision to refocus the scope of the EIS was that cleanup decisions must reflect site-specific cleanup conditions commensurate with the regulatory framework under CERCLA and the Resource Conservation and Recovery Act. The site-specific nature of cleanup is inconsistent with programmatic initiatives that would be implemented nationwide. In other words, for environmental restoration, there is not a proposed program that requires evaluation of programmatic alternatives. Consequently, a PEIS is not an appropriate vehicle for analysis.

Arriving at cleanup decisions on a site-specific basis does not preclude public involvement in such decisions, nor does it alter the Department's commitments and requirements to complete appropriate reviews under NEPA. On the contrary, this permits the necessary specific reviews, considerations, and deliberations for cleanup actions, including considerations of land use issues, to be reached properly with the approval of state and federal regulators and with the direct involvement of the local community.

In addition, with regard to using land use restrictions in setting cleanup levels, the Department has embarked on an extensive initiative to gain an understanding of the long-term future site uses, which is essential to effective planning and decision making for a myriad of Departmental activities. Specifically, this initiative will provide a basis for decision making and for site development and comprehensive planning. Each of the Department's major sites is developing future land use preferences with significant involvement of interested and affected stakeholders.

The Department's Office of Environmental Management (EM) actively seeks the involvement of regulators and other stakeholders in establishing priorities and developing budgets. EM designed a process to give regulators and stakeholders a meaningful voice in developing site priorities, which are then used to develop a budget. The goal of this collaborative effort is to plan what could and could not be done with available resources to try to achieve an optimum balance among priorities within a site, and to some extent, among sites. This process results in a reprioritizing of activities and modification of schedules to ensure that the program will be as effective and cost-efficient as possible. As part of this open decision-making process, national meetings are held with regulators and stakeholders to discuss national priorities and cross-cutting

issues as well as any changes to field budget submissions. The pace as well as the scope of the program, therefore, is taken into consideration and reflected in the priorities and the budget.

The role of site-specific advisory boards and other means of public participation in the decision-making process for cleanup is of critical concern to the Department. The Department has established several advisory boards at its major sites. The boards, which are one means for involving the public, have negotiated their roles and responsibilities. Moreover, agendas are left to the boards to determine in conjunction with the regulators and the Department. The boards are informed of ongoing cleanup activities and issues, including land use planning, budget planning and development, and priority setting, and are invited into the decision-making process.

In the Fiscal Year 1994 National Defense Authorization Acts, Congress directed the Department to provide a life-cycle cost estimate for the program, delineated by specific projects and activities. The *Baseline Environmental Management Report* (BEMR), first issued in 1995 and updated in 1996, systematically analyzed potential life-cycle costs of meeting legal commitments as well as addressing other issues related to the management of hazardous and radioactive materials and waste within DOE The report provided cost estimates associated with various programwide alternatives given differing land use assumptions, residual contamination standards funding and schedule changes, waste treatment, storage and disposal options, and potential technology improvements. This report is a valuable analytical tool for exploring cost consequences of potential options.

In addition, the document *Risks and the Risk Debate: Searching for Common Ground "The First Step"* (DOE, 1995a), when considered with the *Baseline Environmental Management Report* (DOE, 1996) as well as other analyses, helps to provide a foundation of technical, environmental, financial, and social analysis needed to inform the national debate on a number of issues, including those raised in the Council's letter. The purpose of the analysis, prepared in response to direction from the Energy and Water Subcommittee of the Committee on Appropriations, was to help the Department develop a mechanism for establishing priorities among competing cleanup requirements.

After careful consideration of the NRDC's comments, and given these various opportunities for discussion and the analytical tools available for informed debate on national issues, the Department determined that these activities and processes are useful to the public and should continue. Consequently, DOE has begun a "National Dialogue" initiative to provide a means for continuing comprehensive discussions with government officials, regulatory authorities, and other interested organizations and publics regarding the

major materials, waste, and cleanup decisions DOE needs to make. This dialogue includes public participation and input into environmental restoration issues. Nonetheless, the Department decided that the scope of the PEIS should be modified as proposed to consider management of the Department's radiological and hazardous wastes and sites at which the wastes could be managed in the future. This approach is consistent with the alternatives outlined for waste management in the Final Implementation Plan.

Appendix A
References

U.S. Department of Energy. 1995a. *Risks and the Risk Debate: Searching for Common Ground "The First Step," Volumes I and II.* June draft. Washington, DC: Office of Environmental Management.

U.S. Department of Energy. 1996. *The 1996 Baseline Environmental Management Report [BEMR].* DOE/EM-0290. June. Washington, DC: Office of Environmental Management.

Attachment 1
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 55, Number 204, Monday October 22, 1990)
[55 FR 42633]

Department of Energy
"Intent to Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and to Conduct Public Scoping Meetings"

Federal Register / Vol. 55, No. 204 / Monday, October 22, 1990 / Notices 42633

DEPARTMENT OF ENERGY

Intent To Prepare a Programmatic Environmental Impact Statement on the Department of Energy's Proposed Integrated Environmental Restoration and Waste Management Program, and To Conduct Public Scoping Meetings

AGENCY: U.S. Department of Energy (DOE).

ACTION: Notice of intent (NOI) to prepare a programmatic environmental impact statement (PEIS).

SUMMARY: The Department of Energy announces its intent to prepare a PEIS pursuant to the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321, *et seq.*), as amended, and to conduct a series of public scoping meetings nationwide. The PEIS will assess the potential environmental consequences of alternatives for implementing an integrated environmental restoration and waste management program

The purpose of DOE's proposed integrated environmental restoration and waste management program is to provide a broad, systematic approach to addressing cleanup activities and waste management practices. The Department is committed to ensuring that potential risks to human health and the environment from the cleanup of contamination resulting from past operations and from future waste management activities are at safe levels. DOE is further committed to full compliance with environmental regulations and to a goal of completing environmental restoration by 2019.

INVITATION TO COMMENT: To ensure that the full range of issues related to this proposal are addressed, comments on the proposed scope of the PEIS are invited from all interested parties. Written comments to assist DOE in identifying significant environmental issues and defining the appropriate scope of the PEIS should be directed to Mr. Wisenbaker at the address indicated below. Agencies, organizations, and the general public also are invited to present oral comments pertinent to the preparation of the PEIS at the public scoping meetings to be held nationwide, as described below. Written and oral comments will be given equal weight.

Following the completion of the public scoping process, a PEIS Implementation Plan will be issued for public comment. The Implementation Plan will record the results of the scoping process and define the alternatives and issues to be evaluated in the PEIS. DOE intends to

complete the draft PEIS in early 1992. Its availability will be announced in the Federal Register, and public comments again will be solicited. Comments on the draft PEIS will be considered in preparing the final PEIS, scheduled for 1993.

DATES: The public scoping period will continue until February 19, 1991. Written comments should be postmarked by February 19, 1991 to assure consideration. Comments received after that date will be considered to the extent practicable. The public scoping meetings will begin in December 1990. The dates and locations of the meetings will be announced in a subsequent Federal Register notice and in local public notices in advance of the planned meetings.

ADDRESSES AND FURTHER INFORMATION: Written comments on the scope of the PEIS, questions concerning the program, and requests for copies of the draft PEIS should be directed to: Mr. W. E. Wisenbaker, Acting Director, Division of Program Support, Office of Environmental Restoration (EM-43), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 353-2950.

For further information on the DOE NEPA process please contact: Ms. Carol M. Borgstrom, Director, Office of NEPA Oversight (EH-25), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586-4600.

PUBLIC SCOPING MEETINGS: Public scoping meetings will be held in the following cities beginning in December 1990. The dates and locations of these meetings will be published in a subsequent Federal Register notice. This information will also be announced in local public notices before the planned meetings.

Oakland, California
Denver, Colorado
Washington, DC
Tampa, Florida
Atlanta, Georgia
Boise, Idaho
Idaho Falls, Idaho
Chicago, Illinois
Paducah, Kentucky
St. Louis, Missouri
Las Vegas, Nevada
Princeton, New Jersey
Albuquerque, New Mexico
Newburgh, New York
Cincinnati, Ohio
Columbus, Ohio
Portland, Oregon
Columbia, South Carolina
Oak Ridge, Tennessee
Amarillo, Texas
Richland, Washington
Seattle, Washington
Spokane, Washington

SUPPLEMENTARY INFORMATION:

Background. In November 1989, the Secretary of Energy established the DOE Office of Environmental Restoration and Waste Management (EM) for the purpose of consolidating the Department's environmental restoration and waste management activities. In January 1990, the Secretary determined that DOE will prepare an Environmental Impact Statement on a newly proposed integrated environmental restoration and waste management program.

Some of the waste management practices that DOE and its predecessor agencies once considered safe and prudent under then existing requirements and guidelines have resulted in the need for remediation under applicable current Federal and state requirements and guidelines. DOE's environmental restoration activities include the assessment and physical cleanup of contamination at DOE installations and other properties. Environmental restoration activities also include the decontamination and decommissioning (D&D) of DOE's surplus facilities. These facilities and properties may have contamination from radioactive, hazardous, or mixed (radioactive and hazardous) waste. As decisions are made for the handling of contamination at various sites and facilities, new wastes will be generated that will require management.

DOE's waste management operations include the treatment, storage, transportation, and disposal of wastes generated by ongoing nuclear energy, energy research, and defense activities; by environmental restoration activities; and by other sources. These wastes include: high-level radioactive waste (HLW); low-level radioactive waste (LLW); transuranic waste (TRU); mixed waste (MW); greater-than-Class C waste (GTCC) waste; and hazardous waste.

The Affected Installations. DOE's environmental restoration and waste management activities occur throughout the U.S. The largest number of facilities that require environmental restoration or that generate or store the largest volumes of radioactive, hazardous, and mixed waste are located at these installations: Hanford Reservation (Washington); Savannah River Site (South Carolina); Oak Ridge Reservation (Tennessee); Rocky Flats Plant (Colorado); Feed Materials Production Center, Mound Plant and Portsmouth Gaseous Diffusion Plant (Ohio); Idaho National Engineering Laboratory (Idaho); Lawrence Livermore National Laboratory (California); Argonne National Laboratory (Illinois); Paducah Gaseous Diffusion Plant (Kentucky); Nevada Test Site (Nevada); Los Alamos National Laboratory and Sandia National Laboratory (New Mexico); and Pantex Plant (Texas). The Appendix contains a listing of DOE locations where current environmental restoration and waste management activities occur that DOE believes are within the scope of this PEIS. Additional sites may be added in the course of the development of the PEIS.

The Regulatory Framework. Federal laws of major importance to DOE's environmental restoration and waste management activities include, among others, the Atomic Energy Act of 1954 (42 U.S.C. 2011, *et seq.*), as amended; the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) (42 U.S.C. 9601, *et seq.*), as amended; and the Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6901, *et seq.*), as amended. The Atomic Energy Act requires the management, processing, and utilization of radioactive materials in a manner that protects the public health and the environment. CERCLA requires responses to releases or threatened releases of hazardous substances into the environment and establishes a process to clean up abandoned or uncontrolled hazardous waste sites which may endanger public health or the environment. RCRA requires management of waste currently being generated, including the treatment, storage, transportation, and disposal of hazardous waste, and cleanup of hazardous waste releases from past and present operations that pose a threat to human health and the environment. It is DOE's policy to apply NEPA to its waste management and cleanup activities. To minimize delay and duplication of effort in meeting these responsibilities, DOE is supplementing, where necessary, and integrating the procedural documentation and public participation requirements for CERCLA and RCRA to facilitate compliance with NEPA requirements (DOE Order 5400.4, Comprehensive Environmental Response, Compensation, and Liability Act Requirements).

DOE environmental restoration and waste management activities are subject to other applicable Federal and state requirements and to enforceable agreements. Additionally, certain Federal statutes require DOE to undertake specific environmental restoration and waste management activities. For example, under Title I of the Uranium Mill Tailings Radiation Control Act, DOE must remediate inactive uranium milling sites in accordance with Environmental

Protection Agency standards (40 CFR part 192) established for that purpose.

Wastes are categorized in accordance with Federal statutes and regulations and DOE Orders. High-level waste is defined in the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101(12)). Low-level, transuranic, and radioactive mixed wastes are defined in DOE Order 5820.2A (Radioactive Waste Management). Hazardous wastes are those wastes that are defined as hazardous by U.S. Environmental Protection Agency regulations implementing RCRA (40 CFR Part 261) and by applicable state regulations.

Current Practices for Waste Management. To date, DOE's waste management operations have focused on site-by-site treatment, storage, transportation, and disposal of waste. Transuranic, low-level, hazardous, and radioactive mixed waste are generated at many DOE installations; only a few installations generate high-level waste.

DOE generates or stores high-level waste at four installations: the Savannah River Site, the Hanford Reservation, the Idaho National Engineering Laboratory, and the West Valley Demonstration Project. To date, high-level waste has undergone only limited treatment. DOE intends to immobilize the waste in a stable, solid form acceptable for disposal in a geologic repository. Under current law, only one potential repository site (at Yucca Mountain, Nevada) for this waste is currently being characterized.

Most TRU waste has been generated at DOE's Rocky Flats Plant in Golden, Colorado. Transuranic waste is currently stored at several facilities including the Rocky Flats Plant, the Idaho National Engineering Laboratory, the Hanford Reservation, the Oak Ridge Reservation, the Nevada Test Site, Los Alamos National Laboratory, and the Savannah River Site. The Idaho National Engineering Laboratory has the largest management program for this waste. The Department is currently evaluating the Waste Isolation Pilot Plant in Carlsbad, New Mexico, as a potential disposal site for TRU waste.

Low-level waste requires relatively minimal treatment. Although in some instances other methods may be used, DOE currently disposes of the majority of its LLW in near-surface facilities, including installations at the Savannah River Site, the Oak Ridge Reservation, the Nevada Test Site, the Hanford Reservation, Los Alamos National Laboratory, and the Idaho National Engineering Laboratory.

DOE Order 5820.2A (Radioactive Waste Management) requires that the DOE waste equivalent to commercially generated Greater-than-Class C (GTCC) waste be handled as a special case by each site. The Department is also responsible for disposal of commercially generated GTCC waste. DOE has developed a three-part strategy for managing this waste. The first phase would provide a storage facility for those generators that cannot continue to store the waste. The second phase would provide a central storage facility for all commercially generated GTCC waste.

The final phase would transfer the stored waste to a high-level waste repository or provide for the development of a separate GTCC disposal facility.

For hazardous waste, DOE's near-term objective is to treat the waste as it is generated, thereby minimizing the need for storage capacity. DOE disposes of treated hazardous waste in permitted DOE or commercial facilities.

Mixed wastes are generated at many DOE installations. Mixed waste may include high-level waste, transuranic waste, and low-level waste. DOE stores these wastes until they can be treated and disposed of in permitted facilities. The Department currently treats a small amount of MW by thermal destruction to eliminate some hazardous components. In addition, DOE treats some low-level MW by solidification.

The PEIS will address these practices and any reasonable alternatives that are amenable to environmental analysis. (See Scope of PEIS, below)

Current Practices for Environmental Restoration. DOE will continue to seek, to the extent possible, to negotiate a comprehensive Federal Facilities Agreement with the Environmental Protection Agency (EPA) and the involved state to cover its remediation activities at an installation. Such agreements establish technical requirements and schedules for characterization, feasibility assessment and cleanup at each of the affected sites, and delineate the roles and responsibilities of each party to the agreement, to comply with the requirements of Section 120 of CERCLA. DOE is in the early stages of site assessment and characterization at many facilities. These initial activities are being reviewed in compliance with NEPA. DOE has determined that these early remediation activities are normally categorically excluded under its NEPA guidelines (55 FR 37174, September 7, 1990).

Decontamination and decommissioning activities have several objectives: (1) To maintain facilities awaiting additional D&D activities in a manner that protects workers, the public, and the environment; (2) to decontaminate facilities intended for reuse; and (3) decommission other facilities in accordance with requirements set forth in an approved environmental compliance plan. Currently, D&D activities are planned and executed on a site-by-site basis.

The PEIS will address these practices and any reasonable alternatives amenable to environmental analysis.

Need for an Integrated Environmental Restoration and Waste Management Program. The fundamental goal of DOE's Office of Environmental Restoration and Waste Management is to ensure that potential risks to human health and to the environment posed by wastes under its jurisdiction are at safe levels. To help achieve this goal, DOE proposes to conduct an integrated environmental restoration and waste management program.

Historically, DOE environmental restoration and waste management operations have been conducted on a site-by-site basis. This practice has led to differing approaches to cleanup and waste management among DOE sites. DOE's recent consolidation of waste program responsibilities (environmental restoration and waste management) provides the opportunity to establish a systematic approach to programmatic requirements and practices.

Remediation and D & D activities result in large amounts of waste that will require management, in addition to the wastes generated from production, research, and other activities. Because environmental restoration activities will be a significant source of waste, cleanup and waste management activities are closely related. The resolution of certain key issues, such as future land-usability objectives, will determine the amount, type, and timing of environmental restoration waste being introduced into the waste management part of the system. Land-usability policy relates to cleanup standards and the degree of reliance on institutional controls for long-term health and environmental protection.

PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT: On January 12, 1990, the Secretary of Energy determined that a PEIS should be prepared for DOE's newly proposed integrated environmental restoration and waste management program. The Secretary stated that preparation of this PEIS will ensure that a comprehensive and cumulative environmental analysis of waste management proposals and alternatives will be available to DOE decisionmakers and the public.

The PEIS will assess broad programmatic issues and integrated approaches to DOE's environmental restoration and waste management activities. DOE aims, to the extent this is feasible, for the PEIS to provide the primary environmental basis for selecting waste management methods and technologies and the locations at which they would be implemented. However, DOE does not intend the PEIS to assess impacts related to alternative choices of locations within a site. Such detailed decisions would be based on site-specific NEPA documents tiered to this PEIS.

PRELIMINARY DESCRIPTION OF ALTERNATIVES: *Scope of PEIS.* DOE solicits public input on all aspects of the proposed program described in this notice. DOE plans to structure this PEIS in two sections to facilitate public review and comments. One section of the PEIS will focus on key environmental restoration issues. The second section will analyze reasonably foreseeable potential impacts associated with various waste management alternatives within the integrated program.

As discussed previously, current environmental restoration and waste management practices for which reasonable alternatives that are amenable to environmental analysis can be identified are within the scope of the PEIS. Under the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10101, *et seq.*), as amended, DOE currently plans to dispose of high-level waste resulting from Departmental activities in a repository to be developed for spent fuel from commercial nuclear utilities. In addition, under section 213(a) of the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (42 U.S.C. 7272, *et seq.*), as amended, the Department plans to demonstrate the disposal of defense transuranic waste at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. These decisions will not be revisited in the programmatic EIS. In addition, there is a national program, under Congressional direction, to address the management of commercial nuclear reactor spent fuel. The activities associated with that program will be considered in separate NEPA documentation and not in this PEIS. Commercial LLW is not the Department's responsibility and therefore is outside the scope of the PEIS. Uranium Mill Tailings Remedial Action Program (UMTRAP) tailings cleanup and disposal activities are within DOE's purview, but are expected to be close to completion prior to the issuance of the Record of Decision and will not be considered in the PEIS. The groundwater remediation activities associated with UMTRAP are just beginning, however, and therefore are within the scope of this PEIS.

Proposed action. The proposed action is to formulate and implement an integrated Environmental Restoration and Waste Management Program in a safe and environmentally sound manner, and in compliance with applicable laws, regulations and standards. Alternative approaches are discussed below.

Environmental Restoration Analysis: NEPA requires DOE to analyze reasonable alternatives to its proposed actions. DOE realizes that in the current environmental restoration decisionmaking framework for remediation activities there are statutory and regulatory requirements that must be fulfilled. DOE will continue to follow established processes in conducting ongoing environmental restoration activities.

For example, the framework Congress established under CERCLA for remedial actions imposes a strong preference for permanent remedies that comply with all applicable and appropriate requirements established under environmental laws. Consequently, DOE's overall environmental restoration efforts have focused on cleaning up sites adequately for unrestricted future use. The framework also requires that cleanup requirements and remedies be selected site-specifically. This produces final decisions made both discretely and diversely.

DOE believes, however, that there are important national issues that it should analyze in carrying out its responsibilities. These issues include, but are not limited to, (1) the degree to which DOE should rely on proven technologies in contrast to making strong resource commitments to developing innovative technologies; (2) the manner in which DOE should manage wastes until adequate treatment and disposal capacity is available; (3) whether DOE's installations should invariably be cleaned up for unrestricted use; and (4) the environmental basis for deciding cleanup priorities.

DOE seeks to develop and analyze programmatic alternatives that bear on these issues. DOE believes that important information on the costs and benefits of alternative program management strategies could thereby be obtained. DOE is especially interested in receiving public comments on these issues.

Decontamination and decommissioning activities are not subject to the decisionmaking framework that governs remediation activities. DOE proposes, therefore, to approach all D&D activities in an integrated, systematic fashion.

Waste Management Analysis: Waste treatment, storage, transportation, and disposal alternatives primarily depend on the waste category (such as radioactive, hazardous, or radioactive mixed waste). Alternatives will reflect centralized, regional, or installation-specific strategies. The analysis would provide environmental information for deciding which waste management capabilities should be established centrally, regionally, or at each site. Transportation of waste and the potential associated impacts will also be evaluated.

No Action. This alternative would continue present practices. DOE would not adopt and integrated environmental restoration and waste management program. DOE would continue to operate its environmental restoration activities and its waste operations as discrete site-specific actions. If site requirements dictate the need for offsite or new facilities, management decisions would be made on a project specific basis.

DOE would maintain existing facilities for waste management operations. New waste management activities, projects, and technological development would be considered case-by-case.

IDENTIFICATION OF ENVIRONMENTAL ISSUES: The following environmental issues have been identified for analysis in the PEIS. This list is presented to facilitate discussion on the scope of the PEIS and is not intended to be all-inclusive or to predetermine the scope. Therefore, DOE invites comments on these and additional issues relevant to this PEIS.

(1) The potential impacts (both beneficial and adverse) to worker health, public health, and the environment under various alternatives for environmental restoration and waste management.

(2) The potential impacts to workers, public health, and the environment under various alternatives from routine transportation of wastes and potential transportation accidents.

(3) The development of needed technologies and methods for environmental restoration and waste management and the potential impacts (both beneficial and adverse) from their implementation.

(4) Any obstacles to achieving full compliance with all applicable federal, state, and local environmental statutes, regulations, and requirements.

(5) The socioeconomic impacts of alternatives for dispersed, regional, and centralized waste management.

(6) The potential impacts of applying various land-usability strategies to the cleanup of DOE installations and sites.

RELATIONSHIP TO OTHER ACTIONS: *Five-Year Plan.* DOE issued a Five-Year Plan for Environmental Restoration and Waste Management (DOE/S-0070) in August 1989 that was subsequently revised, updated, and reissued (DOE/S-0078P) in June 1990. The Plan summarizes current DOE practices and identifies short- and long-term goals. The activities described are for the near-term (e.g., remediation of seepage basins at the Savannah River Site, and radioactive storage upgrades at the Kansas City Plant). Only general objectives, criteria, and guidance, in addition to those set in applicable environmental regulations and statutes, are specified for implementing environmental restoration and waste management activities on a long-term basis. For example, the Plan states that the majority of solid low-level waste generally will continue to be disposed of using shallow land burial, but recognizes that this may not be suitable for all locations. The Plan also states DOE's general intent that facilities and sites be returned to a condition suitable for unrestricted use, but recognizes that in-place remedies may sometimes be preferred.

The Five-Year Plan is not a proposal within the context of NEPA. Rather, it is preliminary to the Environmental Restoration and Waste Management PEIS in which DOE will evaluate integrating its long-term environmental restoration and waste management activities. The PEIS will specifically address the long-term goals and issues generally summarized in the Five-Year Plan.

As the Plan states, completion of the PEIS process may result in changes in specific programs, which would be reflected in future editions of the Plan.

Environmental Restoration and Waste Management Configuration Study. The Environmental Restoration and Waste Management Configuration Study is a strategic planning study for the long-term (the next 25 years). The study will support the definition of waste system configuration alternatives in this PEIS. DOE intends to issue the draft configuration study concurrently with the draft PEIS for public information and use in reviewing the draft PEIS.

Many factors influence the configuration and updating of DOE's waste management operations, including: (1) Increasingly strict environmental, safety, and health standards and requirements; (2) facilities dating from the late 1940s to the middle 1960s becoming obsolete; (3) increasing costs to maintain and upgrade these facilities; (4) difficulties in managing widely dispersed waste storage facilities in different environmental settings; (5) potential changes in the locations, volumes, and types of waste to be managed, after consideration of a PEIS on reconfiguring (modernizing) the nuclear weapons complex; (6) availability of improved technologies; (7) population growth near once-remote facilities such as areas near Rocky Flats, Colorado, Fernald, Ohio, Oak Ridge, Tennessee, and Livermore, California, which has led to local demands for restricting DOE operations; and (8) transition from waste accumulation and storage to waste treatment and disposal.

PEIS for the Nuclear Weapons Complex (NWC). In concert with the decision to prepare this PEIS, the Secretary decided that a separate PEIS on DOE's proposal to modernize (reconfigure) the nuclear weapons complex will also be prepared. The reconfiguration of the nuclear weapons complex would affect DOE's program for environmental restoration and waste management because it would change the locations, volumes, and types of waste to be managed. The environmental restoration and waste management PEIS, therefore, will take into account, to the extent practical, the materials generated in the preparation of the NWC PEIS. Separate statements are being prepared, however, because the programs are driven by distinct missions, requirements, and schedules. If the PEIS on the NWC is not issued first, DOE will prepare a supplement to the Environmental Restoration and waste management PEIS, if appropriate.

PUBLIC SCOPING MEETINGS AND INVITATION TO COMMENT: DOE is committed to providing opportunities for the involvement of interested individuals and groups in this and other DOE planning activities.

DOE will conduct a series of public scoping meetings nationwide and invites all interested people to attend and to present oral comments concerning: (1) the scope of the PEIS, (2) the issues that should be addressed, and (3) the alternative integrated approaches to be analyzed in the PEIS. DOE also invites written comments.

Oral and written comments will be given equal consideration. Instructions for submitting written comments are given above. People desiring to speak at the public scoping meetings should submit their requests to do so to the contact persons to be designated in a subsequent Federal Register notice. Oral presentation requests for each meeting should be received by DOE at least two days before the meeting.

The meetings will be chaired by a presiding officer. They will not be conducted as evidentiary hearings. Speakers will not be cross-examined, although the DOE representatives present may ask them clarifying questions.

To ensure everyone an adequate opportunity to speak, five minutes will be allotted for each speaker. Depending on the number of persons requesting to speak, the presiding officer may allow more time for speakers representing multiple parties or organizations. Persons wishing to speak on behalf of organizations should identify the organization in their request. Persons who have not submitted a timely request to speak may register at the meetings, and will be called on to speak if time permits. Written comments also will be accepted at the meetings, and speakers are encouraged to provide written versions of their oral comments for the record.

The public scoping meetings will begin in December 1990. Detailed information on the meetings will be provided in a subsequent Federal Register notice. This information will also be announced in local public notices before the planned meetings.

DOE will make a transcript of each meeting. Copies will be made available for inspection at the DOE Freedom of Information Reading Room (Room 1E-190), Forrestal Building, 1000 Independence Avenue SW., Washington, DC 20585, during business hours, Monday through Friday and in local DOE reading rooms. Locations of local reading rooms will be provided in the subsequent Federal Register notice regarding the scoping meetings.

RELATED NEPA DOCUMENTATION: DOE expects to prepare additional NEPA documents for implementing programmatic and facility-specific decisions based upon this PEIS. These generally site-specific documents will analyze future technology and siting alternatives for implementing DOE's environmetnal restoration and waste management activities. Their analyses will address such local concerns as floodplains and wetlands, historic and archaeological sites, land use, and threatened and endangered species. The PEIS will examine these issues only to the degree necessary for selection of an integrated program.

Interim Actions. DOE may need to conduct many diverse and discrete site-

specific environmental restoration and waste management activities while the PEIS is being prepared. Many of these activities are required by Federal and state regulatory agencies under environmental compliance agreements and some are required by court decrees. DOE will have to determine case-by-case whether site-specific actions may proceed before the PEIS is completed. This will be done in accordance with all applicable requirements, including the test for interim actions found in Council on Environmental Quality's NEPA Regulations (40 CFR 1506.1(c)).

Other. DOE has prepared, or is currently preparing, NEPA documents for many of DOE's site-specific actions. Examples of some major relevant waste management NEPA documents are listed below:

1. Final Environmental Impact Statement, Disposal of Hanford Defense High-level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington. DOE/EIS-0113, December 1987. U.S. Department of Energy, Washington, DC.
2. Final Environmental Impact Statement, Waste Management Activities for Groundwater Protection, Savannah River Plant, Aiken, South Carolina. DOE/EIS-0120, December 1987. U.S. Department of Energy, Washington, DC.
3. Final Supplemental Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026-FS, January 1990. U.S. Department of Energy, Washington, DC.
4. Draft Environmental Impact Statement, Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, DOE/EIS-0119d, March 1989. U.S. Department of Energy, Washington, DC.

These documents, the Five-Year Plan (DOE/S-0078P), transcripts from the public scoping meetings (when they become available), and other related documents will be available for inspection at DOE Freedom of Information Reading Rooms.

Issued in Washington, DC, this 15th day of October 1990.

Peter N. Brush,

Acting Assistant Secretary, Environment, Safety and Health.

Appendix: Locations of Activities Embraced by the PEIS

Name	Location
Amchitka Island	Amchitka Island, AK.
Lawrence Berkeley Laboratory.	Berkeley, CA.
University of California	Berkeley, CA.
Atomics International	Canoga Park, CA.
Laboratory for Energy-Related Health Research.	Davis, CA.
Sandia National Laboratory-Livermore.	Livermore, CA.
Lawrence Livermore Laboratory	Livermore, CA.
Bayo Canyon	Los Alamos, CA.
Stanford Linear Accelerator Center.	Palo Alto, CA.
General Atomics	San Diego, CA.
Energy Technology Engineering Center.	Santa Susana, CA.
General Electric Vallecitos Nuclear Center.	Vallecitos, CA.
Rocky Flats Plant	Golden, CO.
Grand Junciton Project Office.	Grand Junction, CO.
Project Rulison Site	Grand Valley, CO.
Project RioBlanco Site	Rifle, CO.
Seymour Speciality Wire	Seymour, CT.
Pinellas Plant	St. Petersburg, FL.
Kauai Test Facility	Kauai, HI.
Ames Laboratory	Ames, IA.
Idaho National Engineering Laboratory	Idaho Falls, ID.
Argonne National Laboratory—West.	Idaho Falls, ID.
Argonne National Laboratory—East.	Chicago, IL.
National Guard Armory	Chicago, IL.
Palos Forest	Chicago, IL.
Fermi National Accelerator Laboratory.	Batavia, IL.
University of Chicago	Chicago, IL.
Johnston Atoll	Johnston Atoll.
Paducah Gaseous Diffusion Plant.	Paducah, KY
Ventron, Beverly	Beverly, MA.
Shpack Landfill	Norton, MA.
W.R. Grace & Co.	Curtis Bay, MD.
General Motors	Adrian, MI.
Hazelwood (Latty Avenue)	Hazelwood, MO.
Kansas City Plant	Kansas City, MO.
St. Louis Airport Storage Site	St. Louis, MO.
Mallinckrodt, Inc.	St. Louis, MO.
St. Louis Airport Storage Site Vicinity Properties.	St. Louis, MO.
Weldon Spring Site Remedial Action Project.	St. Charles, MO.
Tatum Dome	Tatum Dome, MS.
Component Development & Integration Facility	Butte, MT
Hallam Nuclear Power Facility	Lincoln, NE.
Du Pont & Company	Deepwater, NJ.
Kellex/Pierpont	Jersey City, NJ.
Maywood	Maywood, NJ.
Middlesex Landfill	Middlesex, NJ.
Middlesex Sampling Plant	Middlesex, NJ.
New Brunswick Laboratory	New Brunswick, NJ.
Princeton Plasma Physics Laboratory.	Princeton, NJ.
Wayne/Pequannock	Wayne/Pequannock, NJ.
Inhalation Toxicology Research Institute.	Albuquerque, NM.
Sandia National Laboratory—Albuquerque.	Albuquerque, NM.
Ross Aviation	Albuquerque, NM.
Project GNOME Site	Carlsbad, NM.
Waste Isolation Pilot Plant	Carlsbad, NM.
Project GASSBUGGY Site	Farmington, NM.
Los Alamos National Laboratory.	Los Alamos, NM.
Acid/Pueblo Canyon	Los Alamos, NM.
Chupadera Mesa	White Sands Missile Range, NM.
Central Nevada Test Area	Central Nevada Test Area, NV.
Project Shoal Site	Fallon, NV.
Nevada Test Site	Los Vegas, NV
Tonopah Test Range	Nellis Air Force Base, NV.
Colonie	Colonie, NY.
Niagara Falls Storage Site Vicinity Properties.	Lewiston, NY
Niagara Falls Storage Site	Niagara Falls, NY
Ashland Oil Co. #2	Tonawanda, NY
Linde Air Products	Tonawanda, NY.
Seaway Industrial Park	Tonawanda, NY.
Ashland Oil Co. #1	Tonawanda, NY.
Brookhaven National Laboratory.	Upton, Long Island, NY.
West Valley Demonstration Project.	West Valley, NY.
Reactive Metals Inc.	Ashtabula, OH.
Battelle Columbus Laboratories.	Columbus, OH.
Feed Materials Production Center.	Fernald, OH.
Mound Laboratory	Miamisburg, OH.
Piqua Nuclear Power Facility	Piqua, OH.
Portsmouth Gaseous Diffusion Plant.	Portsmouth, OH.
Albany Metallurgical Research Center.	Albany, OR.
Universal Cyclops	Aliquippa, PA.
Center for Energy and Environmental Research.	Mayaguez, PR.
Savannah River Site	Aiken, SC.
Oak Ridge National Laboratory	Oak Ridge, TN.
Oak Ridge Gaseous Diffusion Plant.	Oak Ridge, TN.
Y-12 Plant	Oak Ridge, TN.
Pantex Plant	Amarillo, TX.
Hanford Reservation	Richland, WA.
24 Site Covered under Title I of the Uranium Mill Tailings Radiation Control Act.	Various Locations.

Attachment 2
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 60, Number 15, Tuesday January 24, 1995)
[60 FR 4607]

Department of Energy
"Environmental Restoration and Waste Management; Programmatic Environmental Impact Statement"

Federal Register / Vol. 60, No. 15 / Tuesday, January 24, 1995 / Notices 4607

DEPARTMENT OF ENERGY

Environmental Restoration and Waste Management; Programmatic Environmental Impact Statement

AGENCY: U.S. Department of Energy

ACTION: Notice of opportunity for public comment.

SUMMARY: The Department of Energy is giving the public the opportunity to comment on proposed modifications to the title and scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement. The Department proposes to modify the scope and name of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS).

The proposed action would focus primarily on the evaluation and analysis of waste management issues confronting the Department and would be renamed the Waste Management Programmatic Environmental Impact Statement.

DATES: To ensure that the public's concerns and views are fully considered, DOE is providing a 45-day written comment period that will extend until March 10, 1995, to comment on the proposed modification to the Programmatic Environmental Impact Statement.

ADDRESSES AND FURTHER INFORMATION: Written comments and requests for further information on the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement should be directed to: James A. Turi, Office of Waste Management (EM-33), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585-0002, (301) 903-7147.

For information on the Department's National Environmental Policy Act process, contact: Carol M. Borgstrom, Director, Office of NEPA Oversight (EH-25), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586-4600 or leave a message at 1-800-472-2756.

SUPPLEMENTARY INFORMATION: On October 22, 1990, the Department of Energy issued a Notice of Intent to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS) (55 FR 42633). In the Notice of Intent and in an Implementation Plan issued in January 1994, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." The Notice of Intent and the Implementation Plan identified two separate sets of alternatives to be evaluated, for environmental restoration and for waste management.

The Department attempted to meaningfully analyze the environmental restoration alternatives that it originally defined as part of the "proposed action." After considerable effort, the Department has concluded that it would not be appropriate to make programmatic decisions regarding cleanup strategies that would be applicable to all of the Department's sites. The fundamental reasoning behind the Department's conclusion is that cleanup decisions should reflect site-specific conditions, and, in any event, can only be reached with the approval of state and federal regulators and the involvement of the public. It would be inconsistent with the site-specific nature of cleanup decisions, therefore, to make these decisions under this PEIS that would be implemented nationwide.

Accordingly, the Department proposes to eliminate the analysis of environmental restoration alternatives and to modify the proposed action. As modified, the PEIS would consider how to manage the subject wastes and analyze alternative sites at which the wastes could be managed in the future. The PEIS would focus its programmatic evaluations on waste management facilities, and would henceforth be known as the "Waste Management Programmatic Environmental Impact Statement." As previously set forth in the Implementation Plan, the PEIS would evaluate decentralized, regional, and centralized approaches for storage of high-level waste; treatment and storage of transuranic waste; treatment and disposal of low-level and low level mixed waste; and treatment of hazardous waste. Waste generated by restoration activities in the future that must be managed as part of the Department's program to manage all of its wastes would be considered in the PEIS's projected waste inventories. The draft PEIS is currently scheduled for publication in late spring of 1995.

In the October 22, 1990, Notice of Intent in the Federal Register, the Department of Energy discussed the preparation of a Programmatic Environmental Impact Statement based on formulating and implementing an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable requirements. The Notice of Intent stated that the purpose of the integrated environmental restoration and waste management program was to provide a broad, systematic approach to addressing site cleanup and waste management. Although the proposed action was defined in terms of integrating environmental restoration and waste management, the description of the alternatives in the Implementation Plan set forth separate sets of alternatives for environmental restoration and waste management.

When the Department published the Notice of Intent in 1990, there were important national issues regarding the direction of its environmental restoration program that could be meaningfully evaluated in the PEIS. These issues focused primarily on the level and extent of cleanup of the Department's facilities. The Department continues to believe that cleanup of its sites involves important issues such as land use, public health, worker risks, and cleanup standards. The Department has concluded, however, that programmatic decisions regarding environmental restoration cannot be made because these decisions should reflect the particular conditions at each site, and require the approval of state regulators and the involvement of stakeholders. The Department believes that the proposed action originally considered in the PEIS should be modified by eliminating the analysis of environmental restoration alternatives. In view of this modification the PEIS would be renamed the "Waste Management Programmatic Environmental Impact Statement."

The modified proposed action would focus on the evaluation and analysis of waste management issues confronting the Department and would incorporate potential impacts of environmental restoration on the management of wastes. The Department believes the proposed action as modified will identify and analyze waste management issues and activities for which the Department is responsible. A summary of the comments received in response to this notice will be contained in an appendix to the draft Waste Management Programmatic Environmental Impact Statement. Comments previously received during the public comment process on the scope of the PEIS that are still relevant in light of the proposed modification to the PEIS, and the issues raised by such comments, would be evaluated as discussed in the Implementation Plan. Comments on the scope of the PEIS that are relevant to other analyses being conducted in connection with site-specific environmental restoration at DOE's sites will be considered in the preparation of those analyses.

Issued in Washington, D.C., on January 18, 1995.

Thomas P. Grumbly,
Assistant Secretary for Environmental Management.

[FR Doc. 95-1754 Filed 1-23-95; 8:45 am]

BILLING CODE 6450-01-P

Attachment 3
(to WM PEIS Appendix A)

Federal Register Notice
(Volume 60, Thursday March 16, 1995)
[60 FR 14275]

Department of Energy
"Extension of Public Comment Period for The Environmental Management Programmatic Environmental Impact Statement"

Federal Register / Vol. 60, No. 51 / Thursday, March 16, 1995 / Notices 14275

DEPARTMENT OF ENERGY

Extension of Public Comment Period for the Environmental Management Programmatic Environmental Impact Statement

AGENCY: U.S. Department of Energy.

ACTION: Extension of public comment period.

SUMMARY: On October 22, 1990, the Department of Energy issued a Notice of Intent to prepare the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (PEIS). (55 FR 42633). In the Notice of Intent and in an Implementation Plan issued in January 1994, the Department identified the proposed action as follows: "to formulate and implement an integrated environmental restoration and waste management program in a safe and environmentally sound manner and in compliance with applicable laws, regulations and standards." A notice was issued on January 24, 1995, inviting the public to provide written comments on a proposed modification to the scope and name of the PEIS. (60 FR 4607). In the notice, the Department proposed to modify the proposed action to eliminate the analysis of environmental restoration alternatives. As modified, the PEIS would consider how to manage certain types of radioactive and hazardous waste, and analyze alternative sites at which the wastes could be managed in the future. The PEIS would focus its programmatic evaluations on waste management facilities, and would henceforth be known as the "Waste Management Programmatic Environmental Impact Statement."

INVITATION TO COMMENT: In response to a request from the public, the Department is extending for 30 days, until April 10, 1995, the written comment period for the proposed modification to the Programmatic Environmental Impact Statement. A summary of the comments received in response to this notice will be contained in an appendix to the draft Waste Management Programmatic Environmental Impact Statement.

ADDRESSES AND FURTHER INFORMATION: Written comments and requests for further information on the Programmatic Environmental Impact Statement should be directed to: James A. Turi, Office of Waste Management (EM-33), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585-0002, (301) 903-7147.

For information on the Department's National Environmental Policy Act process, contact: Carol M. Borgstrom, Director, Office of NEPA Policy and Assistance (EH-42), U.S. Department of Energy, 1000 Independence Avenue SW., Washington, DC 20585, (202) 586-4600 or leave a message at 1-800-472-2756.

Issued in Washington, D.C., this 10th day of March 1995.

Thomas P. Grumbly,
Assistant Secretary for Environmental Management.

[FR Doc. 95-6520 Filed 3-15-95; 8:45 am]

BILLING CODE 6450-01-P

Attachment 4
(to WM PEIS Appendix A)

Natural Resources Defense Council's (NRDC's) Comments on the Department of Energy's (DOE's) Proposed Modification in Scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement (Letter: Andrew P. Caputo [NRDC] to James A. Turi [DOE], April 10, 1995)



Natural Resources Defense Council

1350 New York Ave., N.W.
Washington, DC 20005
202 783-7800
Fax 202 783-5917

April 10, 1995

James A. Turi
Office of Waste Management (EM-33)
U.S. Department of Energy
1000 Independence Avenue SW
Washington, D.C. 20585-0002

Dear Mr. Turi:

The Natural Resources Defense Council ("NRDC"), lead plaintiff in NRDC v. Watkins, Civ. No. 89-1835-SS (D.D.C.) (stipulation filed Oct. 22, 1990), files the following comments on the Department of Energy's proposed modification in scope of the Environmental Restoration and Waste Management Programmatic Environmental Impact Statement. Notice of the proposed modification was published in the Federal Register at 60 Fed. Reg. 4,607 (Jan. 24, 1995), and the comment period was extended to today pursuant to a notice published at 60 Fed. Reg. 14,275 (March 16, 1995).

NRDC opposes the proposed modification for both legal and policy reasons. As a legal matter, the National Environmental Policy Act ("NEPA") requires the Energy Department to prepare a programmatic environmental impact statement ("EIS") on its program of environmental restoration activities, for all of the reasons explained in the submissions by NRDC leading up to and during the above-cited litigation. Moreover, during this litigation the Department specifically conceded that its program of environmental restoration and waste management constitutes "'a group of concerted actions' within the meaning of NEPA,"[1] which triggers a duty to prepare a programmatic EIS pursuant to 40 C.F.R. § 1508.18(b)(3). Finally, the Department committed to prepare such a document in the course of the NRDC v. Watkins litigation.

The case for a programmatic EIS on the environmental restoration program is just as strong from a policy perspective as it is from a legal perspective. While it is certainly true that "cleanup decisions should reflect site-specific conditions," 60 Fed. Reg. at 4,608, it is

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[1] Memorandum from James D. Watkins, Secretary, DOE, to Leo P. Duffy, Director, Office of Environmental Restoration and Waste Management, DOE, Jan. 12, 1990.

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equally true that there are a number of important program-level issues relating to the environmental restoration program that demand a full, prospective, program-level analysis with full public participation. These issues include the scope and pace of the environmental restoration program in light of budgetary and other constraints; the choice between using uniform cleanup standards or site-specific cleanup standards as part of the program; the programmatic implications of using land-use restrictions in setting cleanup levels; issues of inter- and intra-facility priority setting, particularly in a situation of budget scarcity; and the programmatic role of site-specific advisory boards and other avenues for public participation in making cleanup decisions. A programmatic analysis of these and other important issues in the environmental restoration program has become even more important in recent months and years, in light of such developments as departmental discussions concerning land-use considerations in the cleanup process, the findings of the Baseline Environmental Management Report, and budget developments.

The need for a program-level analysis of the environmental restoration program is enhanced by the fact that the Department, as a matter of policy, does not perform NEPA compliance on site-specific environmental restoration actions taken pursuant to the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"). Thus, a program-level EIS seems the only NEPA analysis available to citizens on many of the important issues facing the environmental restoration program. Moreover, no alternative to the NEPA process currently exists for analyzing these issues in a programmatic, prospective manner with full public participation.

Sincerely,

Andrew Caputo

Andrew P. Caputo
Attorney

cc: Assistant Secretary Thomas P. Grumbly

Appendix B

Environmental Restoration Wastes

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Acronyms and Abbreviations

The following is a list of the acronyms and abbreviations (including units of measure) used in this appendix.

Ames	Ames Laboratory
ANL-E	Argonne National Laboratory-East
BCL	Battelle Columbus Laboratories
BEMR	*Baseline Environmental Management Report*
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
ERDF	Environmental Restoration Disposal Facility
FEMP	Fernald Environmental Management Project
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	fiscal year
GA	General Atomics
GE	General Electric Vallecitos Nuclear Center
Hanford	Hanford Site
INEL	Idaho National Engineering Laboratory
ITRI	Inhalation Toxicology Research Institute
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LEHR	Laboratory for Energy-Related Health Research
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
m^3	cubic meter(s)
Mound	Mound Plant
NEPA	National Environmental Policy Act
NTS	Nevada Test Site

ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
Pantex	Pantex Plant
PGDP	Paducah Gaseous Diffusion Plant
PORTS	Portsmouth Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RMI	Reactive Metals, Inc.
SNL-NM	Sandia National Laboratories, New Mexico
SPRU	Separations Process Research Unit
SRS	Savannah River Site
TRUW	transuranic waste
WIPP	Waste Isolation Pilot Plant
WM	waste management
WM PEIS	Waste Management Programmatic Environmental Impact Statement
WVDP	West Valley Demonstration Project
Y-12	Y-12 Plant

APPENDIX B
Environmental Restoration Wastes

Certain wastes generated during environmental restoration (ER) activities will be transferred to the Waste Management (WM) Program. The current information available about the ER transferred waste is limited to volumetric estimates by site and waste type (i.e., low-level waste, low-level mixed waste, and transuranic waste. The radiological profiles, chemical contaminant concentrations, and the treatment categories of the individual ER transferred waste streams have not yet been determined to the extent necessary to allow for an evaluation of the potential environmental and human health impacts that would result from management of these ER transferred wastes. Therefore, in this appendix, the assessment as to how the addition of ER transferred wastes may affect WM PEIS alternatives is limited to a qualitative discussion about the potential for affecting WM facility capacities. This discussion is based on the comparison between the expected volumes of ER transferred waste and the volumes of the WM waste at each site. Such analysis, while not of the same scope as the impacts assessment done for WM wastes, is useful to identify those sites and alternatives that could be affected by the addition of ER transferred wastes. When the radiological and chemical contaminant concentration and the treatment categories of ER transferred waste are better known, DOE may be required to assess the impacts of managing ER transferred waste on a site-specific or project basis.

B.1 Introduction

The term "environmental restoration" (ER) refers to the remediation of contaminated media at U.S. Department of Energy (DOE) sites in order to reduce risks and allow sites to be used for other purposes. Depending on the particular site and contaminated media, remediation can occur in place without removal, or the contaminated media may be removed from the environment, generating wastes that would require further treatment or disposal. The majority of the wastes generated during remediation will be managed outside of the alternatives evaluated in the Waste Management Programmatic Environmental Impact Statement (WM PEIS). However, a certain subset of the remediation wastes will be sent for treatment or disposal at waste management (WM) facilities.

This appendix provides estimates of the total amounts of low-level waste (LLW), low-level mixed waste (LLMW), and transuranic waste (TRUW) that are expected to be generated during remediation, as well as estimates of the amounts of these wastes that may be managed by the WM Program. In this appendix, the term "ER transferred wastes" is used to designate those wastes generated by ER that will be transferred to the WM Program. This appendix compares the estimated volumes of ER transferred waste to the volumes of WM wastes analyzed in the WM PEIS and also discusses how the ER transferred wastes may affect the

treatment and disposal capacities of WM facilities. The purpose of the analysis is to identify those WM PEIS alternatives, if any, that could be affected by the addition of ER transferred wastes. This appendix also identifies possible strategies that can be used to accommodate the increased loading of the ER transferred wastes to the WM Program.

Finally, this appendix discusses the assumptions and uncertainties involved in (1) estimating the amount of ER transferred wastes and (2) estimating the effects that ER transferred waste would have on the alternatives in the WM PEIS.

B.2 DOE Environmental Restoration Program

One legacy of the Nuclear Weapons Program is environmental contamination at the sites where research, development, testing, and production of nuclear weapons took place. The Environmental Restoration Program was established to address contaminated media at these sites. The ER Program performs a wide range of activities such as stabilizing contaminated soil, treating groundwater, decommissioning process buildings (including nuclear reactors and chemical separations plants), and exhuming buried drums of waste.

The extent to which a site is "cleaned up" will depend largely on regulatory requirements and decisions regarding future land use. For many sites, the process of evaluating possible uses in the future has just begun. The general process concerning site cleanup actions is laid out by statutes, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC Section 9601 *et seq.*) and the Resource Conservation and Recovery Act (RCRA) (42 USC Section 6905 *et seq.*). The process involves discussions among DOE, regulatory agencies, and local stakeholders. Decisions are implemented at specific sites through formal agreements among DOE, the U.S. Environmental Protection Agency (EPA), and the host state. The process involves several steps. First, a site or portion of a site is characterized to identify contaminants, determine the nature and extent of contamination, and assess potential threats to public health and the environment. Concurrent with characterization, a detailed analysis is performed to quantify risk and evaluate remedial alternatives. A remedy can be implemented quickly, as expedited response actions designed to mitigate conditions that present immediate and significant risks to the environment or human health, or can be performed as part of long-term cleanup.

B.3 Remediation Alternatives and ER Transferred Wastes

The treatment and disposition of wastes generated from site restoration activities can be done under either the DOE ER or WM Programs. Environmental restoration wastes transferred to the responsibility of the DOE WM Program for treatment and disposal are called "ER transferred wastes." The highlighted areas in Figure B.3-1 indicate the ER transferred wastes that are analyzed in this appendix.

Remediation activities are dependent on proposed land uses for each site and can be grouped into two general categories: containment or removal. In the first category, containment, *in situ* remediation and access control serve to reduce the risks by managing contaminated media in their current locations. The second category, *ex situ* remediation, involves removal of the contaminated media, which are then treated and sent for disposal (Figure B.3-1). *In situ* containment remedies (such as capping a landfill or entombing buildings) generate relatively small volumes of ER transferred waste. Typically, remedies using *in situ* technologies, where the contaminated media would remain in place, are coupled with decisions that restrict future site land use.

At those sites where future land-use plans call for less restricted access, it is more likely that remediation would involve removal of contaminated media. Typically, contaminated media that are excavated or facilities that are dismantled will undergo some type of treatment that would generate either a final waste form ready for disposal or a waste stream that will require additional treatment before disposal. In some cases, contaminated media can be removed and sent directly for disposal.

The extent to which ER transferred wastes will use WM facilities is site-specific and depends on such factors as the particular remediation activities at each site and on decisions regarding ER at the site. For example, at the Hanford Site (Hanford), the vast majority of wastes generated during remediation activities are destined for disposal in the Environmental Restoration Disposal Facility (ERDF) (DOE, 1996b). The ERDF is a dedicated disposal facility for ER wastes. Accordingly, Hanford is unlikely to transfer large amounts of ER waste to WM facilities. At sites without dedicated ER facilities, much (or all) of the wastes generated during remediation might become ER transferred waste and would be managed under the alternatives evaluated in the WM PEIS.

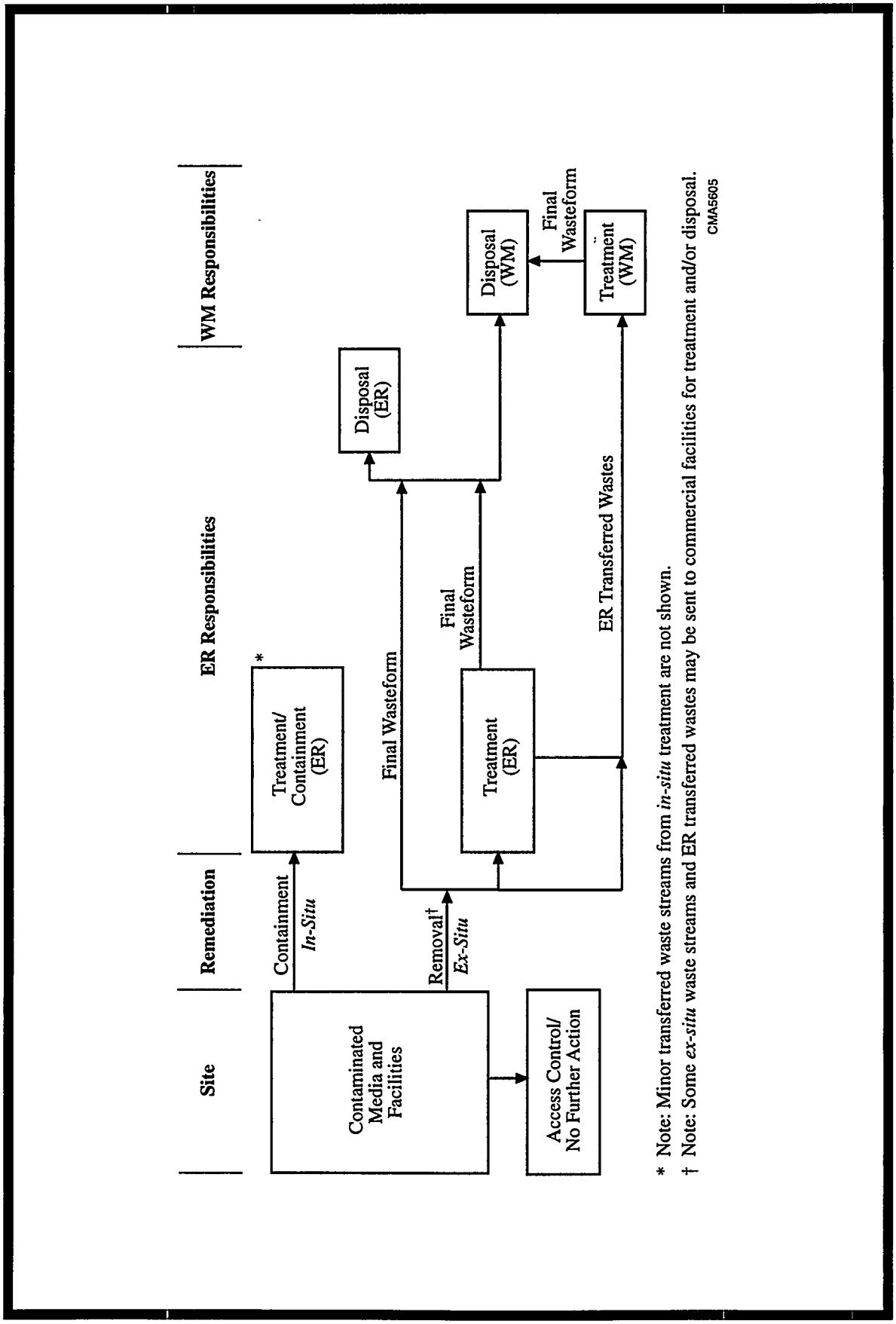


Figure B.3–1. General Remediation Scheme for Contaminated Media and ER Wastes.

B.4 Need to Proceed With Waste Management Decisions Without Assessment of Impacts From ER Transferred Waste

DOE believes that decisions about which sites should host WM treatment, storage, or disposal activities must be made now to make rapid progress toward improving DOE's management of its wastes. Although some ER waste could be transferred for treatment or disposal in WM facilities, possibly influencing the size or siting for these facilities, it was not possible to analyze the potential impacts of managing ER transferred waste in the WM PEIS because there are large uncertainties about ER waste (see Section B.9). DOE believes, however, that the sites for WM facilities must be selected soon. There is a minimum requirement for the siting and sizing of WM facilities based wholly on the locations and quantities of WM wastes and that would remain valid regardless of future ER waste treatment or disposal requirements. When there is better knowledge about the volumes and composition of ER wastes, it is possible that additional WM treatment or disposal capabilities may be needed, which may necessitate further site-specific National Environmental Policy Act (NEPA) analyses. However, these site-specific evaluations would not change the need for the initial set of sites identified to host WM treatment, storage, or disposal activities.

As DOE conducted its analyses of both the ER and WM Programs, it became evident that analyses leading to nationwide programmatic proposals for the ER Program were not appropriate. The Department felt that decisions related to ER were not suited to a national-level analysis but instead should be focused at the site level and reflect site-specific conditions. The ER activities at each site would be best developed on the basis of factors such as the proposed land use, the nature of the contaminated media, the technical solutions available, and local regulatory priorities. Evaluations conducted at the site and local level would be more effective in considering these elements and developing appropriate remediative responses. In contrast, many WM Program decisions are more appropriately addressed at the national level. The nature of WM waste and the requirements for its treatment and disposal are more certain; wastes are either already in storage or will be generated from ongoing processes that are well understood. It is possible and appropriate to develop treatment or disposal capabilities at one or more sites to handle these wastes because the nature and timing of treatment and disposal requirements across many sites are better known. A national-level analysis and programmatic decisions would therefore provide better solutions for the WM Program (see Section 1.7.1).

Consequently, in the *Federal Register* of January 24, 1995, DOE announced that the scope of the WM PEIS would be limited to a programmatic analysis regarding how and where DOE would treat, store, and dispose of its WM waste. The 1995 announcement and the response by the public are contained in Appendix A.

In making decisions about sites that will host WM treatment, storage, or disposal facilities, DOE will consider many criteria. For example, the WM PEIS shows that there is a tradeoff between the impacts resulting from the transport of wastes and the impacts (e.g., health risks and costs) that result from site-specific waste management actions under each alternative. The Decentralized Alternatives minimize transportation risks and associated impacts (such as physical trauma from accidents) but increase the site-specific impacts associated with construction and operation of WM facilities at many sites. The Centralized Alternatives have the greatest transportation impacts and increase the impacts at the chosen central site but decrease the nationwide site-specific impacts and decrease overall costs. The transportation and site-specific impacts associated with the Regionalized Alternatives fall in between those of the Decentralized and Centralized Alternatives. Decisions on which sites will host WM facilities will consider such transportation and site-specific tradeoffs. Sites may be selected to host WM facilities on the basis of a variety of factors, including (1) minimizing the transportation of large quantities of waste, (2) effectively using existing management capabilities, or (3) taking advantage of site-specific conditions (e.g., favorable geology).

When there is sufficient information to evaluate ER transferred wastes, DOE will need to further assess its options. For example, if ER transferred waste is located at a site that already is selected to have certain WM facility capabilities, DOE would have to determine whether the site facilities should manage the additional waste and whether additional NEPA analysis would be required to examine the impacts resulting from the addition of the ER transferred wastes. If the ER transferred waste is present at a site not selected for a WM facility, DOE would evaluate whether new WM capabilities should be added to the site or whether the wastes should be transported to a site with the capability to manage the waste. Any additional NEPA evaluations are likely to be project- or site-specific and would consider how the ER activities and ER transferred waste at one site should be managed, given the existence of a set of WM facilities with varying capacities and capabilities, as well as commercial waste treatment and disposal capabilities. The future evaluation of options for managing ER transferred wastes will be facilitated by having more operating experience at the WM facilities and improved knowledge of costs, effectiveness, and environmental effects.

The following sections of Appendix B provide general information on the estimated volumes of ER wastes.

B.5 Estimated Volumes of Contaminated Media and ER Transferred Wastes

DOE has prepared projections of the volumes of contaminated media and the waste that may be generated by remedial activities. The information on ER waste volume presented in this appendix is updated from data in *The Current and Planned Low-Level Waste Disposal Capacity Report, Revision 0* (DOE, 1996a). Additional information about the amounts of contaminated media and facilities at DOE sites is contained in *The 1996 Baseline Environmental Management Report* (BEMR) (DOE, 1996b). The BEMR looked at more than 10,000 contaminated sites and facilities and applied generic "base case" (the base case is detailed in the Summary and Volume 1 of the BEMR) criteria, such as potential site land use and the technical feasibility of processing certain media, to identify possible remedial actions and to estimate the volume of waste that might be generated.

For DOE sites addressed in this appendix, the total volume of radioactively contaminated media is approximately 58 million cubic meters (m^3). Tables B.5–1 through B.5–3 present the anticipated disposition and volumes of LLW, LLMW, and TRUW, respectively, from ER.

DOE does not expect to generate any high-level waste by remedial activities. Hazardous waste generated during remediation would be sent to offsite commercial facilities for final disposition and thus is not analyzed in this section.

Environmental restoration activities are site-specific. Of the total volume of contaminated media, approximately 36,000,000 cubic meters would be managed without physically removing or excavating the media, either through access controls or *in situ* treatment or both. Of this volume, approximately 11,000,000 cubic meters are media for which an appropriate response may be access control alone (where public access to the area is restricted either through land deeds or a barrier such as a fence and posted warnings). At some sites (e.g., LANL), some of the contaminated media may require no further action. The other 25,000,000 cubic meters would be managed by *in situ* treatment and containment technologies such as capping.

Approximately 8,500,000 cubic meters would be removed and managed in planned ER facilities that would only handle LLW and LLMW generated by onsite remediation. An additional 1,600,000 cubic meters of LLW and LLMW would be removed and sent to commercial facilities for disposal (e.g., DOE currently sends some waste to the Envirocare facility in Utah; other commercial disposal facilities will be considered

Table B.5–1. Planned Disposition of LLW From Environmental Restoration Actions

DOE Sites Analyzed in the WM PEIS		Estimated Volume for Each Type of Response Action[a] (m^3)						TOTAL by Site
		Ex Situ, Managed by ER	*Ex Situ*, Transferred to WM	*Ex Situ*, Commercial Disposal	*In Situ* Treatment or Containment	Access Controls Only and/or No Further Action	Not Yet Determined	
ANL-E		0	8,700	20	0	0	0	8,800
BNL		0	400	120,000	0	0	0	120,000
FEMP		1,800,000	180,000	480,000	0	0	5,800	2,500,000
Hanford		3,900,000	700	0	20,000,000	0	0	24,000,000
INEL		420,000	140,000	0	79,000	0	0	640,000
LLNL		0	0	0	0	0	0	0
LANL		0	15,000	0	200,000	8,900,000	110,000	9,300,000
NTS		0	1,100,000	0	1,200	0	0	1,100,000
ORR		30,000	9,800	850,000	51,000	0	0	940,000
Pantex		54	0	0	0	0	0	0
PGDP		770,000	150	0	0	56	0	770,000
PORTS		730,000	190	0	0	0	0	730,000
RFETS		61,000	36,000	0	0	0	0	96,000
SNL-NM		0	36,000	0	0	14,000	0	50,000
SRS		0	400,000	0	310,000	1,800	1,800,000	2,500,000
WVDP		0	0	0	0	0	0	0
Other Sites	Chicago Offsite	0	0	15,000	0	0	0	15,000
	FUSRAP	260,000	0	16,000	0	0	2,200	270,000
	Mound	0	3,100	120,000	0	0	0	120,000
	Nevada Offsite	0	0	0	26,000	0	0	26,000
	RMI	0	30,000	0	0	0	0	30,000
	Others	1,400	24,000	1,000	0	0	0	26,000
	Subtotal	260,000	57,000	150,000	26,000	0	2,200	500,000
TOTAL		8,000,000	1,900,000	1,600,000	21,000,000	8,900,000	1,900,000	
							GRAND TOTAL	= 43,000,000

Notes: Projected actions assume the "base case" scenario as described in *The 1996 Baseline Environmental Management Report* (DOE, 1996b). The actions are for nonliquid contaminated media and facilities; they exclude groundwater because of the high level of uncertainty in estimating volumes. For *ex situ* response actions, a relatively small quantity of waste that is already in storage is also included in the estimated volumes.

[a] Volumes are in cubic meters rounded to two significant figures; therefore totals may not sum exactly.

Source: May 1996 approved version of the "Environmental Restoration Core Database" (DOE, 1996c).

Table B.5-2. Planned Disposition of LLMW From Environmental Restoration Actions

DOE Sites Analyzed in the WM PEIS		Estimated Volumes for Each Type of Response Action[a] (m^3)						TOTAL by Site
		Ex Situ, Managed by ER	*Ex Situ*, Transferred to WM	*Ex Situ*, Commercial Disposal	*In Situ* Treatment or Containment	Access Controls Only and/or No Further Action	Not Yet Determined	
ANL-E		160	0.4	0	140,000	0	0	140,000
BNL		3,200	0	16,000	0	0	0	19,000
FEMP		0	2,200	2,400	0	0	0	4,600
Hanford		220	100	0	0	0	0	320
INEL		100,000	0	65	99,000	0	0	200,000
LLNL		0	0	0	0	0	0	0
LANL		0	0	980	0	500,000	0	500,000
NTS		0	50	0	0	0	0	50
ORR		0	3,900	0	0	450,000	1,900	460,000
Pantex		0	0	0	0	0	0	0
PGDP		210,000	0	0	0	240,000	0	450,000
PORTS		380	0	0	0	270,000	0	270,000
RFETS		140,000	42,000	0	9,900	180,000	0	380,000
SNL-NM		0	0	1,700	0	2,600	0	4,300
SRS		0	150,000	0	3,900,000	0	6,600,000	11,000,000
WVDP		0	0	0	0	0	0	0
Other Sites	FUSRAP	7,200	0	12,000	0	0	0	19,000
	LBL	0	0	0	42,000	0	0	42,000
	Nevada Offsite	0	0	0	11,000	0	0	11,000
	Other	96	4,400	520	0	0	0	5,000
	Subtotal	7,300	4,400	12,000	54,000	0	0	78,000
TOTAL		470,000	200,000	34,000	4,200,000	1,600,000	6,600,000	
							GRAND TOTAL =	13,000,000

Notes: Projected actions assume the "base case" scenario as described in *The 1996 Baseline Environmental Management Report* (DOE, 1996b). The actions are for nonliquid contaminated media and facilities; they exclude groundwater because of the high level of uncertainty in estimating volumes. For *ex situ* response actions, a relatively small quantity of waste that is already in storage is also included in the estimated volumes.

[a] Volumes are in cubic meters rounded to two significant figures; therefore totals may not sum exactly.

Source: May 1996 approved version of the "Environmental Restoration Core Database" (DOE, 1996c).

Table B.5-3. Planned Disposition of TRUW From Environmental Restoration Actions

DOE Sites Analyzed in the WM PEIS		Estimated Volumes for Each Type of Response Action[a] (m^3)					TOTAL by Site
		Ex Situ, Managed by ER	*Ex Situ*, Transferred to WM	*In Situ* Treatment or Containment	Access Controls Only and/or No Further Action	Not Yet Determined	
ANL-E		0	190	0	0	0	190
BNL		0	0	0	0	0	0
FEMP		0	0	0	0	0	0
Hanford		0	1,800	0	0	84	1,900
INEL		0	9,700	0	0	0	9,700
LLNL		0	0	0	0	0	0
LANL		0	0	4,400	0	0	4,400
NTS		0	0	0	0	0	0
ORR	ORNL	12	1,400	130	0	0	1,600
	Y-12	0	50	0	0	0	50
	Subtotal	12	1,500	130	0	0	1,600
Pantex		0	0	0	0	0	0
PGDP		7	0	0	0	0	7
PORTS		0	0	0	0	0	0
RFETS		0	1,900	0	0	3,000	4,900
SNL-NM		0	0	0	4,000	0	4,000
SRS		0	65,000	0	0	0	65,000
WVDP		0	0	0	0	0	0
Other Sites	BCL	0	95	0	0	0	95
	GE	20	0	0	0	0	20
	SPRU	0	36	0	0	0	36
	Subtotal	20	130	0	0	0	150
TOTAL		39	80,000	4,500	4,000	3,100	
						GRAND TOTAL =	91,000

Note: Projected actions assume the "base case" scenario as described in *The 1996 Baseline Environmental Management Report* (DOE, 1996b). The actions are for nonliquid contaminated media and facilities; they exclude groundwater because of the high level of uncertainty in estimating volumes. For *ex situ* response actions, a relatively small quantity of waste that is already in storage is also included in the estimated volumes.

[a] Volumes are in cubic meters rounded to two significant figures; therefore totals may not sum exactly.

Source: May 1996 approved version of the "Environmental Restoration Core Database" (DOE, 1996c).

as they become available). At certain sites, approximately 2,200,000 cubic meters of LLW, LLMW, and TRUW will be removed and transferred to the WM Program for final treatment or disposal. It is these "transferred" wastes that are addressed in this appendix. Finally, because some sites (1) have not yet developed an ER strategy, (2) do not yet have sufficient data to estimate the volume of contaminated media, or (3) disposition only fractions of certain media, the dispositions of some 8,500,000 cubic meters of contaminated media are not yet determined.

Some site-specific ER activities are described below (Source: 1996 BEMR [DOE, 1996b]).

Argonne National Laboratory-East (ANL-E). Environmental restoration activities at ANL-E are conducted under RCRA corrective action guidelines. There are several types of ER projects scheduled at ANL-E. "Treatment site projects" include soil, groundwater, and sediment media. Up to 70% of these areas are assumed to require no further action. "Solid waste storage and disposal projects" cover the investigation and remediation of contamination resulting from landfills, disposal wells, and leaking underground storage tanks. Additional projects are the Mixed Waste Storage and Disposal Sites (317/319 Areas) Project and decommissioning activities at the Facilities Conversion, Reactor Facilities, and Support Facilities operable units.

Future ER activities at ANL-E are estimated to generate about 8,800 cubic meters of LLW, almost all of which is expected to be transferred to WM facilities. Approximately 140,000 cubic meters of LLMW is expected to be addressed by the ER Program at ANL-E; very little of this waste is anticipated to enter into the WM system because current planning assumptions are that *in situ* treatment or containment technologies would be used to stabilize these areas of contamination. DOE anticipates that all of the TRUW that will be generated by ER activities at ANL-E (approximately 190 cubic meters) will be transferred to WM facilities.

Brookhaven National Laboratory (BNL). The ER Program at BNL is conducted under an RCRA/CERCLA Interagency Agreement between the EPA and the New York Department of Environmental Conservation. Groundwater is the principal contaminated medium at BNL. The current planning assumptions are that the BNL ER Program would transfer small quantities of its waste to WM for limited treatment (i.e., volume reduction and stabilization) prior to shipment off site for disposal. The majority of LLW and LLMW generated by ER activities is planned to be sent to offsite commercial facilities for treatment or disposal. Only 400 cubic meters of ER transferred LLW would be sent to WM facilities out of 120,000 cubic meters of LLW generated by remedial actions. No LLMW is expected to be sent to WM.

Fernald Environmental Management Project (FEMP). Remedies have been selected for all of the five operable units (OUs) at FEMP under the CERCLA process. For the OU 1 waste pits, the remedy includes removal, treatment (as necessary), and offsite disposal at a permitted commercial disposal facility. DOE anticipates that wastes that do not meet the waste acceptance criteria for the commercial facility would be shipped to the Nevada Test Site (NTS). Operable Unit 4 consists of two earthen-bermed concrete silos (Silos 1 and 2) containing K-65 residues, which are high-specific-activity, radium-bearing wastes; one concrete silo containing metal oxides (Silo 3); and one unused concrete silo. The selected remedy for OU 4 involves removal, vitrification, and offsite disposal of the materials in Silos 1, 2, and 3 at NTS. The majority of the wastes from the remaining OUs will be disposed of in an onsite disposal cell. Wastes that do not meet the acceptance criteria of the onsite disposal facility would be shipped off site for disposal at commercial facilities.

Up to 180,000 cubic meters of LLW and 2,200 cubic meters of LLMW are expected to be transferred to the WM Program. An estimated 1,800,000 cubic meters of LLW are planned to be managed onsite, while 480,000 cubic meters are anticipated to be shipped to a commercial disposal facility. Approximately 2,400 cubic meters of LLMW are planned to be shipped to a commercial facility.

Hanford Site. Environmental restoration activities at Hanford are conducted under the authority of the Tri-Party Agreement among the DOE, EPA, and the Washington State Department of Ecology. The Hanford Site has numerous areas with contaminated surface and subsurface soils and has several large plumes of contaminated groundwater. The ER activities also cover the decontamination and decommissioning of up to 800 buildings. The vast majority of the LLW and LLMW generated during ER activities would be managed within the ER Program. Excluding the wastes that would be treated *in situ*, the majority of the waste would be disposed in the Environmental Restoration Disposal Facility.

The ER Program at Hanford will manage approximately 24,000,000 cubic meters of LLW and 320 cubic meters of LLMW. Of these amounts, only 700 cubic meters of LLW and 100 cubic meters of LLMW are expected to be transferred to the WM Program. Approximately 1,800 cubic meters of TRUW would be transferred to the WM Program out of a total of 1,900 cubic meters.

Idaho National Engineering Laboratory (INEL). The ER Program at INEL operates within the framework of the Federal Facility Agreement/Consent Order signed in 1991 by the DOE, EPA, and the State of Idaho. The INEL has 98 OUs grouped into 10 waste areas. Waste Area Groups 8 and 9 cover the Argonne National Laboratory-West and the Naval Reactor Facility sites, respectively. Wastes generated

during remediation will be sent to either the ER Program or WM Program for final treatment and disposal. Since fiscal year (FY) 1986, a total of 381 potentially contaminated area or sites have been identified at INEL.

Approximately 140,000 cubic meters of LLW would be transferred to the WM Program out of 640,000 cubic meters of LLW generated by site remediation. All 200,000 cubic meters of LLMW would be managed within the ER Program. All 9,700 cubic meters of TRUW generated by remediation would be managed by the WM Program.

Lawrence Livermore National Laboratory (LLNL). Environmental restoration activities at the LLNL Main Site and Site 300 are conducted as two distinct projects and are governed by separate Federal Facility Agreements among the DOE, EPA, and the California Environmental Protection Agency Department of Toxic Substance Control and Regional Water Quality Control Boards. Assessments at the Main Site have focused on determining the extent of groundwater contamination and, as necessary, implementing cleanup actions that deal with the following three issues: capturing the western offsite plume, capturing the southern offsite plume, and interior source control and mass removal. Site 300 activities have included assessing the extent of both onsite and offsite soil and groundwater contamination, with treatment of trichloroethylene-contaminated groundwater beginning in 1991. Additional cleanup actions are currently planned at LLNL, some of which will continue to generate hazardous wastes that would be shipped to offsite commercial facilities. No LLW, LLMW, or TRUW is projected to be generated as a result of these cleanup actions.

Los Alamos National Laboratory (LANL). Environmental restoration at LANL is designed to meet the requirements of the facility's RCRA operating permit. The 2,100 potentially contaminated areas at LANL are grouped into six field units. As of FY 1995, one hundred of the areas had been remediated, with no further action proposed for up to 900 sites.

About 15,000 cubic meters of LLW generated from ER projects would be transferred to WM facilities for treatment or disposal. An estimated 980 cubic meters of LLMW would be sent off site for commercial treatment and disposal. All 9,700 cubic meters of TRUW generated by site cleanup would be transferred for disposal within the WM Program. Plans are to address the remaining media contaminated with LLW or LLMW by using *in situ* treatment or containment technologies. In addition, a large number of sites, containing almost 9,000,000 cubic meters of contaminated media, have been proposed for no further action.

Nevada Test Site (NTS). Environmental restoration at NTS is conducted according to RCRA guidelines under a Federal Facility Agreement and Consent Order. There are approximately 2,400 corrective action sites within the NTS and Tonopah Test Range that require some level of investigation and possible remediation under the ER Program. The sites have been grouped into three categories: (1) industrial sites, which include all sites used in support of testing operations; (2) soil sites, which include all surface and shallow subsurface soil contamination resulting from nuclear tests; and (3) underground test areas, which are sites that were impacted by underground testing of nuclear devices. From a waste generation standpoint, cleanup of the soil sites, which would involve excavation and bulk disposal of contaminated soil in an appropriate subsidence crater, represents the largest potential volume of ER generated wastes at NTS. As an interim action, DOE and the State of Nevada have negotiated a radionuclide concentration action level of 200 picocuries per gram, which would result in approximately 1,100,000 cubic meters of LLW that would be transferred into the WM Program for disposal. One of the major assumptions used to estimate the future waste contribution from these activities is that the final cleanup action level for plutonium would be near the 200-picocurie-per-gram level.

Oak Ridge Reservation (ORR). The ER Program at ORR is conducted under a 1992 Federal Facility Agreement and covers the K-25 Site, the Oak Ridge National Laboratory (ORNL), and the Y-12 Plant (Y-12). The K-25 Site has numerous solid waste management units and contaminated buildings. At ORNL, there are approximately 350 sites contaminated with radioactivity or hazardous chemicals. The sites are grouped into 20 waste area groupings, 13 of which are identified as potential sources of contamination. Areas of potential contamination at Y-12 are consolidated into three hydrologic, geographic units. Because of the large number of contaminated sites or buildings, remedial actions at ORR are site-specific and depend on the location and type of contaminated media, as well as the sources of contamination. For the most part, large volumes of radioactively contaminated soils and facilities to be decommissioned would be stabilized in place.

At ORR, the ER Program would manage approximately 940,000 cubic meters of LLW, 460,000 cubic meters of LLMW, and 3,100 cubic meters of TRUW. Approximately 9,800 cubic meters of LLW, 3,900 cubic meters of LLMW, and 2,900 cubic meters of TRUW are expected to be transferred to the WM Program.

Paducah Gaseous Diffusion Plant (PGDP). At PGDP, the DOE has retained responsibility for ER and related WM activities, and the United States Enrichment Corporation has assumed operation of the production portion of the plant. Most investigation and remediation activities at the site are subject to RCRA

and CERCLA regulations. There are 204 potential release sites (solid waste management units) grouped into 28 waste area groupings that are being addressed by the ER Program. Two groundwater contamination plumes are known to extend beyond the boundaries of the plant (a northwest plume and a northeast plume); both have been the subject of considerable ER activity. In addition, the ER Program is planning for the eventual decommissioning activities, which will be undertaken once the uranium enrichment processing facilities are no longer needed.

Current ER planning assumptions are that 770,000 cubic meters of LLW would be generated by the remedial and decommissioning activities, almost all of which is expected to be handled by the ER Program, either using offsite disposal facilities or through construction of an onsite disposal facility. Only 150 cubic meters of LLW is currently planned to be transferred to the WM system. At present, 240,000 cubic meters of LLMW is anticipated to remain on site, in an area with long-term institutional controls. Another 210,000 cubic meters of LLMW is expected to be generated and dispositioned by using either commercial facilities or possibly an onsite engineered disposal cell. Approximately 7 cubic meters of TRUW is estimated to be generated during remedial action and decommissioning activities and is expected to be managed by the ER Program, with possible future shipment to WIPP.

Pantex Plant. The ER Program at Pantex addresses 144 solid waste management units and 114 potential release sites that have been grouped into 15 OUs for investigation and cleanup. RCRA Facility Investigations have been initiated for all OUs. Activities to date have resulted in no adverse environmental impacts based on the RCRA and NEPA reviews and evaluations performed on a project-specific level. Future cleanup activities are expected to be of a similar nature, with a gradual decrease in intensity as more sites reach closure. The ER work is expected to generate 54 cubic meters of LLW. Beginning in FY 1997, the WM Program will assume responsibility for characterization, packaging, treatment, storage, and disposal of the relatively small volume of LLW generated by ER activities.

Portsmouth Gaseous Diffusion Plant (PORTS). At PORTS, the DOE has retained responsibility for ER and related WM activities, and the United States Enrichment Corporation has assumed operation of the production portion of the plant. Environmental restoration activities at PORTS are done under RCRA guidelines. Assessments conducted as part of the RCRA corrective action process have found that soil and groundwater underlying portions of the plant are contaminated with various solvents. The groundwater contamination appears to be limited to the shallow aquifer, which is not used for drinking water, and remains within the boundaries of the plant. Remedial actions have been completed at several sites, and

additional actions are ongoing or are currently in the planning stages. The ER Program is planning for the eventual decommissioning activities that will be undertaken once the uranium enrichment processes are no longer needed.

The majority of the LLW and LLMW expected to be generated in the future at PORTS would come from decommissioning activities. It is assumed that the gaseous diffusion facilities would be removed to ground level, and several low-profile disposal mounds would be located where the former structures stood. Consequently, a total of about 730,000 cubic meters of LLW and 270,000 cubic meters of LLMW are slated to be managed under the ER Program. These wastes are not scheduled to be transferred to WM facilities.

Rocky Flats Environmental Technology Site (RFETS). Environmental restoration activities at RFETS are conducted under an interagency agreement among DOE and Federal and State stakeholders. There are 16 OUs contaminated with hazardous and radioactive substances. The OUs include ponds, creeks, reservoirs, holding pads, trenches, storage pads, and ground surfaces and belowground areas. Several contaminated sites (OU 3) lie off site of the RFETS. In addition, the decommissioning of more than 400 structures is planned for the site. Contaminated media include soils, surface water, groundwater, sediments, and debris. Remedial actions planned for the site would utilize new and currently operating waste treatment facilities, including a soil-washing facility, a wastewater treatment facility, and a disposal facility.

The majority of the wastes generated during ER activities (61,000 cubic meters of LLW and over 320,000 cubic meters of LLMW) would be managed on site by the ER Program. Of this total, approximately 190,000 cubic meters of LLMW is expected to be managed via *in situ* containment or access controls. A Corrective Action Management Unit is expected to be ready in FY 1997 to dispose of LLW and LLMW soil and debris. This unit will be designed to meet RCRA performance standards. An additional 36,000 cubic meters of LLW, 42,000 cubic meters of LLMW, and 1,900 cubic meters of TRUW are expected to be transferred to WM facilities.

Sandia National Laboratories, New Mexico (SNL-NM). The ER Program at SNL-NM is being conducted under the authority of RCRA. Beginning in FY 1995, SNL-NM no longer divided the site up into OUs for purposes of ER activities. According to the 1996 BEMR, SNL-NM expects to establish a Corrective Action Management Unit under RCRA to dispose of hazardous wastes. For LLW, the current strategy is to ship such waste off site to NTS after using volume-reduction technologies to the extent practicable. LLMW is

expected to be treated on site and then disposed of as hazardous waste in the Corrective Action Management Unit or as LLW at NTS.

All 36,000 cubic meters of contaminated LLW media removed at the site would be transferred to the WM Program. An additional 14,000 cubic meters of contaminated media would be managed in place using access controls.

Savannah River Site (SRS). The ER Program at SRS is governed by a variety of regulatory requirements, including State and Federal laws, interagency agreements, and various settlement and consent decrees. Under CERCLA, in 1993, the DOE, EPA, and the South Carolina Department of Health and Environmental Control entered into a Federal Facility Agreement. Some remedial actions at inactive waste units have been conducted under the authority of the site's 1987 RCRA permit. At SRS, there are over 1,000 facilities potentially contaminated with hazardous and radioactive materials. Contaminant migration from some of the structures has resulted in groundwater contamination. The potential migration of contaminants is a public health concern. More than 90 areas of potential contamination are currently being characterized or remediated. An additional 478 areas are undergoing preliminary evaluation. An estimated 25% of these areas are expected to require a complete assessment and remediation.

Current SRS estimates are that approximately 400,000 cubic meters of ER generated LLW will have transferred to WM, out of a total 2,500,000 cubic meters of LLW generated by remedial actions at SRS. An additional 150,000 cubic meters of LLMW is expected to be transferred to the WM Program. Approximately 4,000,000 cubic meters of LLMW would be managed within the ER Program. All of the 65,000 cubic meters of TRUW generated by remediation would be transferred to the WM Program. The disposition of up to 8,400,000 cubic meters of ER media has not yet been determined.

West Valley Demonstration Project (WVDP). All wastes at WVDP are managed within the WM Program.

B.6 Estimated ER Transferred Waste Loads

Estimates of ER transferred waste are derived from the base case criteria as outlined in the BEMR (DOE, 1996b). Future site land-use decisions are a crucial factor in determining the base case remedial actions at

a site and the amount of transferred waste that will be produced during ER activities. Land-use choices can range from "restricted," where the area will be subject to restrictive access controls, to "unrestricted," where the public will have full access to the site. Unrestricted use options are also known as "greenfield" access.

Table B.6–1 provides a summary, by waste type, of the ER transferred wastes and the corresponding WM waste. Hazardous waste generated during ER is not included because such waste will most likely be sent off site for commercial treatment. The data are site-specific for the ER transferred waste totals. Some of the ER transferred wastes may be in a stable form that would only require disposal at WM facilities. These stabilized wastes would only affect disposal facilities, not WM treatment facilities.

B.7 Potential Effects of ER Transferred Waste Inputs to the WM PEIS Analyses

In this appendix, the relative volumes of ER transferred wastes are compared with WM waste volumes to determine whether there may be effects on the WM alternatives. Where facility capacity allows, the treatment of ER transferred waste would be conducted during the planned 10-year treatment time frame; and, if capacity is limited, treatment of ER transferred waste might continue for as much as 20 years beyond the WM treatment period (see Section B.8). In this appendix, potential effects of overloading on site treatment facility capacity are noted for those waste types, sites, and alternatives where the ER transferred waste load is equal to or greater than 100% of the volume of the comparable WM inputs. This level represents a doubling of the waste loading to the affected WM facility.

For sites where the volume of ER transferred waste is greater than 100% of the corresponding volume of WM waste, the additional waste loads could be managed by either utilizing up to 30 years of WM facilities' operating capacity or by increasing the capacity of the facilities. Volumes of ER waste that are less than 100% of comparable WM wastes could most likely be handled by utilizing the longer operational period and thus would not require increasing the facilities' capacity. If additional facility capacity were required, future NEPA analyses could evaluate the impacts of increasing WM facility capacity.

Tables B.7–1 through B.7–3 show a comparison, by site, between the expected volumes of ER transferred waste and the volumes of WM waste for each alternative. The tables also show the percentage ratio between the ER and WM wastes. As shown in Tables B.7–1 through B.7–3, the volume of ER transferred wastes

Table B.6-1. Total Site Volumes (m^3) of WM Wastes and ER Transferred Wastes[a]

	LLW		LLMW		TRUW	
Site	ER Transferred	WM	ER Transferred	WM	ER Transferred[b]	WM
ANL-E	8,700	6,700	0.4	160	190	1,300
BNL	400	5,600	0	190	0	0
FEMP	180,000	0[c]	2,200	2,600	0	0
Hanford	700	89,000	100	36,000	1,800	50,000
INEL	140,000	105,000	0	35,000	9,700	39,000
LANL	15,000	150,000	0	2,800	0	11,000
LLNL	0	3,200	0	4,300	0	1,700
NTS	1,100,000	1,700	50	3,000	0	610
ORR	9,800	270,000	3,900	59,000	1,500	2,700
Pantex	54	2,700	0	690	0	0
PGDP	150	50,000	0	600	0	14
PORTS	190	97,000	0	33,000	0	0
RFETS	36,000	41,000	42,000	21,000	1,900	6,200
SNL-NM	36,000	2,500	0	100	0	0
SRS	400,000	510,000	150,000	20,000	65,000	17,000
WVDP	0	42,000	0	55	0	0.5
Others[d]	57,000	130,000	4,400	1,000	130	1,500
Total	1,900,000	1,500,000	200,000	220,000	80,000	132,000

[a] May 1996 Approved Version of the "Environmental Restoration Core Database" (DOE, 1996c).
[b] Includes mixed TRUW.
[c] All FEMP LLW considered as ER.
[d] Others include Mound, RMI, LBL, Ames, BCL, ITRI, GA, GE, and LEHR.

may exceed 100% of the comparable WM wastes at ANL-E, NTS, FEMP, INEL, and SNL-NM for LLW; at RFETS and SRS for LLMW; and at SRS for TRUW.

Table B.7-4 shows, for each treatment alternative and waste type, the number of sites that would be affected by the addition of ER transferred waste. Overall, the addition of the ER waste would affect less than 25% of the treatment sites for most alternatives. The only effect on a Centralized Alternative would be for LLW, due to the large amount of LLW projected for NTS.

However, since it is likely that the bulk of the ER transferred LLW at NTS (primarily consisting of soils) would be treated on site using minimal treatment, the effects of this large waste load on the treatment facilities' LLW Regionalized and Centralized Alternatives would be minimized. In a similar fashion, the

Table B.7–1. Comparison of Total Volumes of ER Transferred LLW to WM LLW by Alternative

Site	Decentralized (Minimal Treatment Only at All Sites)			Centralized 3 and 4 (Treatment at 7 Sites)			Centralized 5 (Treatment at 1 Site)		
	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM
ANL-E	8,700	6,700	130%	--[a]	--	--	--	--	--
BNL	400	5,600	7%	--	--	--	--	--	--
FEMP	180,000	0	NA[b]	--	--	--	--	--	--
Hanford	700	89,000	<1%	700	95,000	<1%	1,900,000	1,500,000	136%[d]
INEL	140,000	105,000	130%	1,200,000	107,000	11×[c,d]	--	--	--
LANL	15,000	150,000	10%	51,000	150,000	32%	--	--	--
LLNL	0	3,200	0%	--	--	--	--	--	--
NTS	1,100,000	1,700	650×[c]	--	--	--	--	--	--
ORR	9,800	270,000	4%	10,000	300,000	3%	--	--	--
PGDP	150	50,000	<1%	--	--	--	--	--	--
Pantex	54	2,700	2%	--	--	--	--	--	--
PORTS	190	97,000	<1%	220,000	290,000	76%	--	--	--
RFETS	36,000	41,000	88%	36,000	41,000	88%	--	--	--
SNL-NM[e]	36,000	2,500	14×[c]	--	--	--	--	--	--
SRS	400,00	510,000	78%	400,000	515,000	78%	--	--	--
WVDP	0	42,000	0%	--	--	--	--	--	--
Other	57,000	130,000	41%	--	--	--	--	--	--

Table B.7–1. Comparison of Total Volumes of ER Transferred LLW to WM LLW by Alternative—Continued

Site	Regionalized 2 (Treatment at 11 Sites)			Regionalized 4 (Treatment at 7 Sites)			Regionalized 5 (Treatment at 4 Sites)		
	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM
ANL-E	--	--	--	--	--	--	--	--	--
BNL	--	--	--	--	--	--	--	--	--
FEMP	190,000	46,000	410%	--	--	--	--	--	--
Hanford	700	89,000	<1%	700	96,000	<1%	700	96,000	<1%
INEL	1,200,000	107,000	11×[c]	1,200,000	107,000	11×[c,d]	1,300,000	300,000	430%
LANL	51,000	150,000	32%	51,000	150,000	32%	--	--	--
LLNL	0	8,000	0%	--	--	--	--	--	--
NTS	--	--	--	--	--	--	--	--	--
ORR	9,800	270,000	4%	10,000	320,000	3%	230,000	600,000	38%
PGDP	150	50,000	<1%	--	--	--	--	--	--
Pantex	0	2,700	<1%	--	--	--	--	--	--
PORTS	30,000	230,000	13%	220,000	280,000	76%	--	--	--
RFETS	36,000	41,000	88%	36,000	41,000	88%	--	--	--
SNL-NM[e]	--	--	--	--	--	--	--	--	--
SRS	400,000	510,000	78%	400,000	510,000	78%	400,000	516,000	78%
WVDP	--	--	--	--	--	--	--	--	--
Other	--	--	--	--	--	--	--	--	--

Note: Waste volumes in total cubic meters.
[a] Not a treatment site under the alternative.
[b] All LLW at FEMP is ER waste.
[c] For clarity, factor increase is used instead of %.
[d] Under some alternatives, actual onsite ER transferred waste loads at INEL and Hanford would be reduced by use of minimal treatment onsite at NTS and SNL-NM.
[e] Includes ITRI.

Table B.7–2. Comparison of Total Volumes of ER Transferred LLMW to WM LLMW by Alternative

Site	Decentralized (Treatment at 16 Sites)			Regionalized 1 (Treatment at 11 Sites)			Regionalized 2 and 3 (Treatment at 7 Sites)		
	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM
ANL-E	0.4	160	<1%	--[a]	--	--	--	--	--
BNL	0	190	0%	--	--	--	--	--	--
FEMP	2,200	2,600	85%	2,200	2,800	79%	--	--	--
Hanford	100	36,000	<1%	100	36,000	<1%	100	41,000	<1%
INEL	0	35,000	0%	50	38,000	<1%	50	38,000	<1%
LANL	0	2,800	0%	0	2,900	0%	0	3,500	0%
LLNL	0	4,300	0%	0	4,700	0%	--	--	--
NTS	50	3,000	2%	--	--	--	--	--	--
ORR	3,900	59,000	7%	3,900	59,000	7%	3,900	60,000	7%
PGDP	0	600	0%	0	600	0%	--	--	--
Pantex	0	690	0%	0	690	0%	--	--	--
PORTS	0	33,000	0%	0	33,000	0%	2,200	36,000	6%
RFETS	42,000	21,000	200%	42,000	21,000	200%	42,000	21,000	200%
SNL-NM	0	100	0%	--	--	--	--	--	--
SRS	150,000	20,000	750%	150,000	20,000	750%	150,000	20,000	750%
WVDP	0	55	0%	--	--	--	--	--	--
Other	4,400	1,000	--	4,400	--	--	--	--	--

Table B.7-2. Comparison of Total Volumes of ER Transferred LLMW to WM LLMW by Alternative—Continued

Site	Regionalized 4 (Treatment at 7 Sites)			Centralized (Treatment at 1 Site)		
	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM
ANL-E	--	--	--	--	--	--
BNL	--	--	--	--	--	--
FEMP	--	--	--	--	--	--
Hanford	100	41,000	--	200,000	220,000	91%
INEL	42,000	62,000	68%	--	--	--
LANL	--	--	--	--	--	--
LLNL	--	--	--	--	--	--
NTS	--	--	--	--	--	--
ORR	5,100	96,000	5%	--	--	--
PGDP	--	--	--	--	--	--
Pantex	--	--	--	--	--	--
PORTS	--	--	--	--	--	--
RFETS	--	--	--	--	--	--
SNL-NM	--	--	--	--	--	--
SRS	150,000	20,000	750%	--	--	--
WVDP	--	--	--	--	--	--
Other	--	--	--	--	--	--

Note: Waste volumes in total cubic meters.
[a] Not a treatment site under the alternative.

Table B.7–3. Comparison of Total Volumes of ER Transferred TRUW to WM TRUW by Alternative

Site	Decentralized (Treatment at 16 Sites)			Regionalized 1 and 2 (Treatment at 6 Sites)			Regionalized 3 (Treatment at 4 Sites)			Centralized (Treatment at 1 Site)		
	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM	ER (m^3)	WM (m^3)	ER as % of WM
ANL-E	190	1,300	15%	--[a]	--	--	--	--	--	--	--	--
BNL	0	0	--	--	--	--	--	--	--	--	--	--
FEMP	0	0	--	--	--	--	--	--	--	--	--	--
Hanford	1,800	50,000	4%	1,800	50,000	4%	1,800	50,000	4%	--	--	--
INEL	9,700	39,000	25%	9,700	39,000	25%	12,000	56,000	21%	--	--	--
LANL	0	11,000	0%	0	11,000	0%	--	--	--	--	--	--
LLNL	0	1,700	0%	--	--	--	--	--	--	--	--	--
NTS	0	610	0%	--	--	--	--	--	--	--	--	--
ORR	1,500	2,700	56%	1,700	2,700	56%	1,700	2,700	63%	--	--	--
PGDP	0	14	0%	--	--	--	--	--	--	--	--	--
Pantex	0	0	--	--	--	--	--	--	--	--	--	--
PORTS	0	0	--	--	--	--	--	--	--	--	--	--
RFETS	1,900	6,200	31%	1,900	6,200	31%	--	--	--	--	--	--
SNL-NM	0	0	--	--	--	--	--	--	--	--	--	--
SRS	65,000	17,000	390%	65,000	18,000	360%	65,000	18,000	360%	--	--	--
WVDP	0	0	--	--	--	--	--	--	--	--	--	--
WIPP	--	--	--	--	--	--	--	--	--	80,000	130,000	62%

Note: Waste volumes in total cubic meters.
[a] Not a treatment site under the alternative.

Table B.7-4. Number of Sites Potentially Affected by the Addition of ER Transferred Wastes by Alternative

Waste Type	Decentralized: All Sites Treat	Regionalized: 11 Sites Treat	Regionalized: 7 Sites Treat	Regionalized: 6 Sites Treat	Regionalized: 4 Sites Treat	Centralized: 1 Site Treats
LLW	4/16 [a]	1/11	1/7	NA[b]	1/7	1/1
LLMW	2/16	2/11	2/7	NA	1/4	0/1
TRUW	1/10	NA	NA	1/6	1/4	0/1

[a] Indicates the number of WM treatment sites where the volume of ER transferred waste ≥ 100% of the WM waste volume, compared with the total number of treatment sites.
[b] Not applicable.

potential impacts on the Regionalized Alternatives for LLMW and TRUW are also due to large waste inputs from one or two sites (i.e., RFETS and SRS for LLMW and SRS for TRUW) rather than to substantial ER inputs at a large number of sites. Again, the site-specific treatment capacities could be expanded to accommodate the increased loading resulting from the addition of ER waste. There would be no effects to the Centralized Alternative for LLMW and TRUW.

B.8 Assumptions

The estimates of the volumes of ER transferred wastes that would be managed in WM facilities and the effects of such wastes on WM PEIS alternatives were based on several assumptions:

- All of the waste identified as ER transferred wastes would, in fact, be transferred to the WM Program.
- Although the proportional distribution of wastes may differ, ER transferred wastes are assumed to fall into the same treatability groups as the WM waste for each waste type and can therefore be processed in WM treatment plants.
- The majority of the ER wastes generated over the 75-year period evaluated in the BEMR (DOE, 1996b) would actually be produced between 2003 and 2033.
- ER transferred wastes would be sent to the WM Program during site remediation. The ER transferred wastes may be sent gradually during the remediation activities or all at once, depending on the specific ER operations.
- If shipped to other sites for treatment or disposal, ER transferred wastes would follow the same transport configuration as WM wastes.

- Once there is sufficient information to characterize ER transferred wastes, they would fall within the waste treatment categories already identified in characterizing WM wastes. In other words, it is unlikely that there would be a novel category of ER transferred waste that would be unlike any of the treatment categories of WM waste.
- All wastes identified as ER transferred wastes in this appendix would require some type of treatment, although the type of treatment cannot be determined until the wastes are characterized.
- Current ER data combine both TRUW and mixed TRUW. It is expected that the majority of transuranic-contaminated media will be TRUW.
- All ER transferred waste is likely to be contact-handled.
- Although plans to manage contaminated media are proceeding independent of the WM Program, excess WM facility capacity can be used for ER transferred wastes; after the planned 10-year facility operations period for WM wastes, as much as 20 years of additional operational treatment capacity of these facilities would be available to treat ER transferred wastes and newly generated WM wastes.
- The radiological activity of ER transferred waste would be lower than the activity of corresponding WM wastes.
- The ER transferred waste estimates do not include waste volumes for which no feasible remedial technology is available; these volumes were therefore not included in the base case (e.g., underground soils at nuclear test sites, major contaminated aquifers).
- Hazardous waste would be treated and disposed of at commercial facilities to the maximum extent practical.
- The majority of ER transferred LLW would require only minimal treatment to meet health and safety requirements prior to disposal. Minimal treatment (i.e., packaging) would be done at the site generating the waste.

B.9 Uncertainties

Determination of the effects that the addition of ER transferred wastes would have on the capabilities of WM facilities and on the alternatives evaluated in the WM PEIS depends on many factors. Major considerations include assumptions on future site land use and remedial actions, changes in WM technologies, the radiological composition and activity of ER transferred wastes, and changes in the characterization of contaminated media and facilities at DOE sites. The uncertainties inherent in estimating

the effects of ER wastes on WM facilities may affect final decisions on WM PEIS alternatives. The following factors contribute to the uncertainties:

- The adoption of alternate land uses than those assumed in the BEMR may alter the amounts of ER transferred waste. More restrictive access policies at each site and across the DOE complex would result in lower amounts of ER transferred waste going to WM facilities. Conversely, the adoption of less restrictive access policies would likely increase the volume of waste generated by ER actions. This could, in turn, increase the amount of ER transferred waste. For example, current BEMR projections estimate up to a 77% increase in costs for the most unrestricted greenfield uses. This scenario would be expected to create a comparable increase in the ER waste loads. However, adoption of the most unrestricted land use is unlikely. The choice of land uses between restricted and unrestricted uses would result in only minor changes in expected cleanup costs and, by extension, waste volumes (see 1996 BEMR [DOE, 1996b]: Table 9 and Figure 11, Executive Summary).
- Future ER decisions at each site could alter the amount of ER transferred wastes that would be sent to WM facilities for final disposition. If DOE decides that more sites will have their own ER management facilities, the result would be lower amounts of ER waste that would be transferred to WM facilities.
- Effects are also dependent on the volume of ER transferred wastes that require treatment and disposal, compared with those that will require disposal only. As considered here, all ER transferred wastes are assumed to require some treatment; however, it is likely that a sizable amount of the ER transferred waste load would require only disposal at WM facilities. The current ER data do not separate those ER transferred wastes that require treatment and disposal from wastes that would require only disposal. The final treatment and disposal volumes will only be determined when the contaminated media are removed.
- Because the ER transferred wastes would be shipped as generated during site cleanup, the volume that would be delivered to WM facilities at any given time is uncertain. If a site's wastes were generated early in remedial operations, all or a substantial portion of the estimated ER transferred waste might be sent to WM facilities in a relatively short time. Large loadings of ER transferred waste may have greater effects on WM waste storage facilities than on treatment and disposal facilities because even if a facility has adequate capacity to accommodate additional waste loading within the 30-year time frame, there may not be sufficient storage capacity to hold the wastes until they can be processed.
- This appendix only identifies the potential volumetric effects of sending ER transferred waste to WM treatment facilities. Because current data do not characterize the radiological composition or activity concentration of this waste, the additional contaminant emissions resulting from the treatment of ER waste and the subsequent additional impacts on human health and the environment cannot be directly quantified. However, because the radiological activities and chemical contaminant concentrations of ER

transferred waste are expected to be lower than those for the corresponding WM wastes, the direct impacts on human health and the environment from treating ER transferred wastes would likely be lower than those for processing similar volumes of WM wastes. The ultimate effects of the treatment of ER transferred wastes can only be determined when a site's contaminated media are removed and characterized prior to treatment.

- This appendix assumes that all of the ER transferred waste would be sent for treatment in WM facilities. However, future decisions may direct some of the ER transferred waste to commercial facilities. This would lessen the potential effects of ER transferred wastes on WM facilities.
- Because the exact radiological and chemical composition of the ER transferred waste is not yet known, it is possible that as more data about waste composition become available, the type categorization of ER transferred wastes could change. For example, the presence or absence of hazardous chemicals in the waste could alter the distribution between LLW and LLMW. Similarly, more detailed information about the levels of alpha-radionuclide activities in ER transferred waste could change the distribution between TRUW and LLW or LLMW.
- Although ER transferred wastes are expected to fall into the waste treatment categories already identified for WM wastes, the proportional distribution of the ER wastes among the treatment categories may not be the same as the distribution for WM wastes at a site. The ER transferred wastes can only be placed into specific treatment categories after determination of their chemical, radiological, and physical characteristics. Since such characterization can only be done after the ER wastes are generated, there is uncertainty in the amounts of ER transferred waste and in the treatment that they will require.

B.10 References

DOE. *See* U.S. Department of Energy.

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Appendix C

Environmental Impacts Analysis Methods

Appendix C in the Final WM PEIS contains material formerly found in Appendix I in the Draft WM PEIS.

U.S. Department of Energy
Waste Management Programmatic Environmental Impact Statement

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Acronyms and Abbreviations

The following is a list of acronyms and abbreviations (including units of measure) used in this appendix.

Acronyms

AAL	ambient allowable limit
AAQS	Ambient Air Quality Standards
ACHP	Advisory Council on Historic Preservation
AGDSP	aboveground disposal module
ANL-E	Argonne National Laboratory-East
AQCR	Air Quality Control Region
ARARs	Applicable or Relevant and Appropriate Requirements
BEA	Bureau of Economic Analysis
BHDSP	borehole disposal
BNL	Brookhaven National Laboratory
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	chlorofluorocarbons
CH	contact-handled
CISV	canister storage vault
CPI	consumer price index
D&D	decontamination and decommissioning
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
FEMP	Fernald Environmental Management Project
FTE	full-time equivalent
GCR	General Conformity Rule

HAPs	hazardous air pollutants
HI	hazard index
HLW	high-level waste
HW	hazardous waste
INEL	Idaho National Engineering Laboratory
I-O	input-output system
LANL	Los Alamos National Laboratory
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MEI	maximally exposed individual
MDVS	modular dry vault storage
NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NTS	Nevada Test Site
O&M	operations and maintenance
ODS	ozone-depleting substance
ORR	Oak Ridge Reservation
PCBs	polychlorinated biphenyls
PGDP	Paducah Gaseous Diffusion Plant
PLCC	program life-cycle cost
PORTS	Portsmouth Gaseous Diffusion Plant
PPI	producer price index
PSD	prevention of significant deterioration
RFETS	Rocky Flats Environmental Technology Site
RH	remote-handled
RIMS	Regional Input-Output Modeling System
ROI	region of influence

SEL	significant emission level
SHOP	State Historic Preservation Officer
SIDSP	silo disposal module
SLDSP	shallow land disposal module
SNL-NM	Sandia National Laboratories-New Mexico
SRS	Savannah River Site
STOSI	silo storage module
TAP	toxic air pollutant
TRUW	transuranic waste
VMT	vehicle mile traveled
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant
WM	waste management
WMFCI	Waste Management Facility Cost Information
WM PEIS	Waste Management Programmatic Environmental Impact Statement
WVDP	West Valley Demonstration Project

Abbreviations

BTU	British thermal unit
CO	carbon monoxide
gpd	gallons per day
L	liter
μg	microgram
m^3	cubic meter
mg	milligram
mph	miles per hour
mrad	millirad
mrem	millirem
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
Pb	lead
pCi	picocurie
PM_{10}	particulate matter equal to or less than 10 micrometers in diameter
SO_2	sulfur dioxide
yr	year

APPENDIX C
Environmental Impacts Analysis Methods

The Waste Management Programmatic Environmental Impact Statement (WM PEIS) environmental impacts analysis was accomplished using an engineering analysis of generic designs developed for the treatment, storage, and disposal facilities required to manage each waste type at the sites, and estimates of transportation requirements. Outputs from the engineering analysis were estimates of resource requirements, environmental discharges, and costs. These outputs were used as inputs to evaluate human health risk, environmental, socioeconomic, and cultural resources, and impacts at the sites and along the transportation corridors, and were the basis for discussions of environmental justice issues.

C.1 WM PEIS Environmental Impacts Analysis Approach

The environmental resources for which detailed impacts analysis methods are presented in this appendix include:

- ***Cost***
- ***Air Quality***
- ***Water Resources***
- ***Ecological Resources***
- ***Economic Resources***
- ***Population Impacts***
- ***Environmental Justice***
- ***Land Use***
- ***Infrastructure***
- ***Cultural Resources***

The environmental impacts for the five waste types were evaluated using an analytical process consisting of three phases for the waste management alternatives. This three-phased approach was applied as applicable in the analysis of treatment, transportation, storage, and disposal activities for each of the waste types at the 17 major U.S. Department of Energy (DOE) sites. The three phases, as shown in Figure C.1-1, were: (1) a Generic Design Engineering Analysis Input Phase; (2) an Engineering Analysis Output Phase; and (3) an Environmental Impacts Analysis Phase. It should be noted that in addition to the relationships indicated in Figure C.1-1, there are significant interrelationships between areas identified in the "Environmental Impact Analysis" phase. For example, facility discharges are directly linked to human health effects. Health risk effects in turn form the basis for the environmental justice analysis. The details of these relationships are presented in the remainder of this appendix.

Engineering Analysis Using a Generic Design. In the first phase, DOE made assumptions regarding waste loads for the five waste types. These assumptions related to the volume of waste currently in inventory and anticipated from future operations of DOE facilities and to its physical (gaseous, liquid, solid), chemical, and radiological characteristics. DOE then routed these estimated waste loads among specified DOE sites

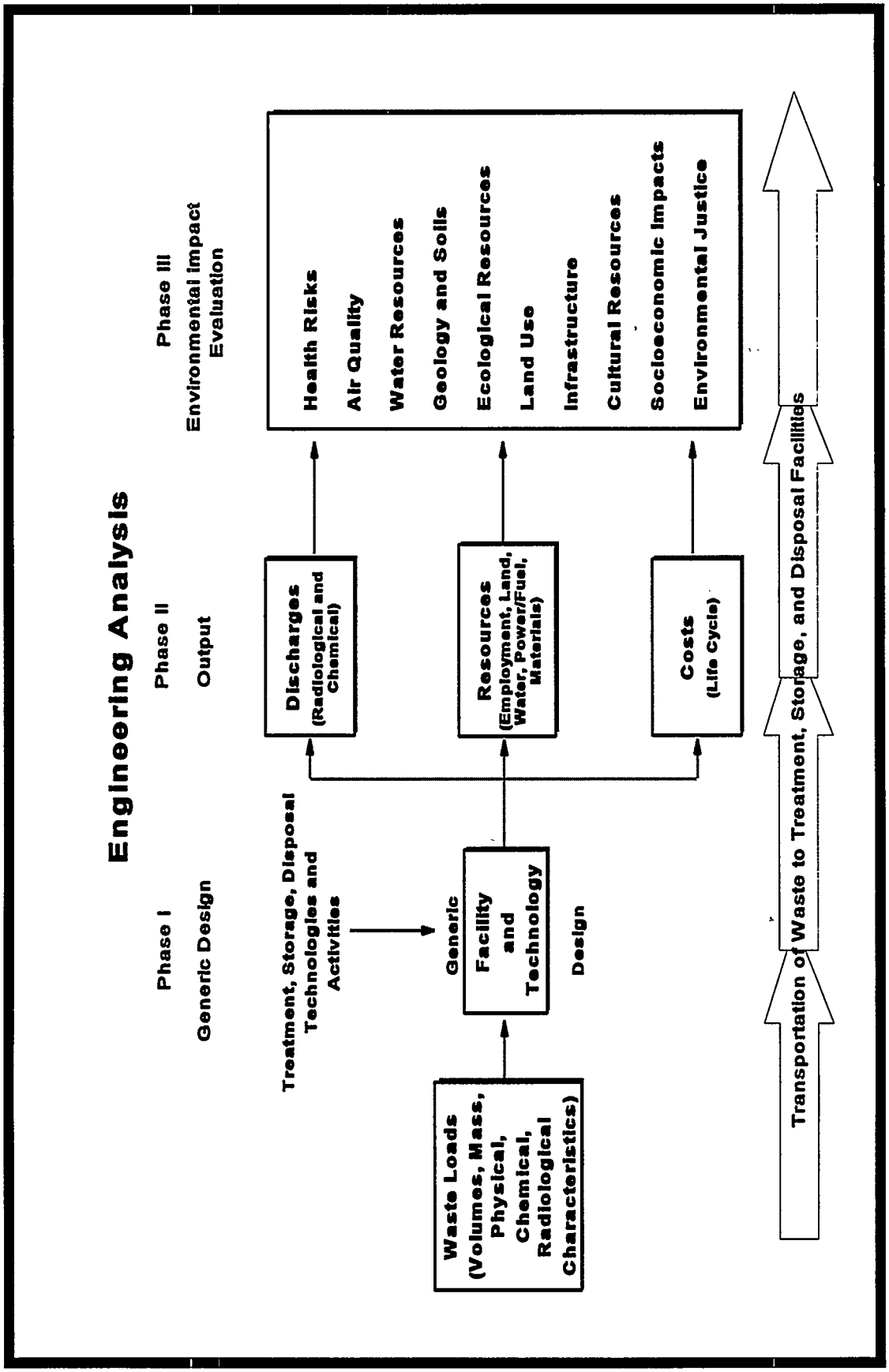


Figure C.1-1. WM PEIS Analytical Relationships.

according to certain criteria based on the closest site with appropriate treatment capabilities as defined for each of the waste management alternatives to determine how much waste would be handled at each site under each alternative. DOE also developed a generic design of the waste management processes and facilities and selected one technology option for purposes of analysis. The facilities considered and the technology chosen for each waste type, and the rationale for that selection, are described more fully in the waste-type chapters.

Engineering Analysis Output. In the second phase, the waste loads allocated to each site under each alternative were generically "processed" through a mathematical model of the generic waste management (WM) facility design, and estimates of outputs were obtained for the amounts and rates of radiological and chemical effluents released to the environment, volume and rates of resources required or consumed, numbers of full-time equivalent (FTE) workers required, and costs to build, operate, maintain, decontaminate and decommission the WM facilities.

Environmental Impact Evaluation. In the third phase, the effluents, resources, and costs became the input for evaluation of environmental and socioeconomic impacts, and human health risks.

C.2 Phase I: Engineering Analysis Using a Generic Design

C.2.1 Waste Loads

Waste Volumes. The WM Programmatic Environmental Impact Statement (PEIS) impact and cost analyses used DOE and U.S. Environmental Protection Agency (EPA) databases for waste inventories and generation rates. However, these databases are constantly upgraded, and a cutoff date was established for the data to allow the analyses to proceed.

Sources of data for each of the waste types are listed below and described in detail in the waste type chapters (Chapter 6–10) and Appendix I:

- **Low-level mixed waste (LLMW)**—The *Mixed Waste Inventory Report* (DOE, 1994) was used for all LLMW inventories and generation rates, except for Colonie, ETEC, and RFETS, whose generation

rates and inventories come from late 1994 site estimates, and ANL-E and NTS, whose generation rates and inventories come from the *Mixed Waste Inventory Summary Report* (DOE, 1995a).

- **Low-level waste (LLW)**—The *Integrated Data Base for 1992* (DOE, 1992) was used for generation rates and inventories of stored waste except for BNL, NTS, ORR, Pantex, and WVDP, whose generation rates and inventories come from the updated *Integrated Data Base Report - 1994* (DOE, 1995d). The Waste Management Information System (ORNL, 1992) was consulted for data not available in the Integrated Data Base.
- **Transuranic waste (TRUW)**—The *Integrated Data Base for 1992* (DOE, 1992) and the *Interim Mixed Waste Inventory Report* (DOE, 1993a) were used for TRUW inventories and generation rates except for Hanford and SRS. SRS generation rates and inventories come from the updated *Mixed Waste Inventory Summary Report* (DOE, 1995a), while Hanford's come from the *Waste Isolation Pilot Plant Transuranic Waste Baseline Inventory Report* (BIR-2) for 1995 (DOE, 1995e).
- **High-level waste (HLW)**—Site-specific plans and NEPA documents for Hanford, INEL, SRS, and WVDP were used for HLW volume and canister production rates.
- **Hazardous waste (HW)**—The EPA Information System biennial and annual reports (EPA, 1991a) were used for HW generation rates. Offsite shipments to commercial treatment were derived from DOE fiscal year 1992 HW shipping manifests.

It is DOE policy that sites employ pollution prevention practices to reduce the amount of waste generated. The databases from which estimates of annual generation were obtained did not fully consider pollution prevention efforts. Possible impacts of pollution prevention are discussed in Appendix G.

The waste loads analyzed in this PEIS do not include wastes that may be generated as a result of environmental restoration (ER) activities. The anticipated ER waste loads are described in the waste-type chapters (Chapters 6–10) on a site-by-site basis, and compared to the anticipated WM waste loads at those sites. It is not anticipated that HLW will be generated through ER activities. These chapters also contain a qualitative discussion of the extent to which ER waste loads could affect the conclusions regarding environmental impacts.

Treatability Groups. While this PEIS covers five waste types, those wastes are not homogenous and are derived from thousands of different waste streams. Thus, the wastes were combined into treatability groups for purposes of developing treatment system designs. Each treatability group is identified with one or more of the five waste types considered in the PEIS and a treatment method, where appropriate, that EPA

recognizes as meeting the requirements of the Resource Conservation and Recovery Act (RCRA) (42 USC 6901 *et seq.*). For the PEIS analyses, the physical structure of the waste was used for the initial sort for treatability. At the most basic level of analysis, all waste can be grouped into six physical categories using common engineering criteria design parameters, which also served as the initial set of treatability categories:

- **Aqueous liquids**—Primarily water with organic content less than 1% (such as wastewater)
- **Organic liquids**—Liquids and slurries with organic content greater than 1% (such as solvents)
- **Organic and inorganic sludge and particulates**—Solid and semi-solid material other than debris (such as sludge from treatment plants, resins, and solids less than 2.5-inch diameter particle size)
- **Soils**—Contaminated soils (such as contaminated earth requiring remediation)
- **Debris**—Solid material exceeding 2.5-inch diameter particle size that is either (1) manufactured, or (2) plant or animal matter, or (3) discarded natural or geological material (such as cobblestones)
- **Other**—Special waste streams (such as batteries, laboratory packs, reactive metals, and toxic metals, which include mercury, lead, and beryllium)

Four waste types use this basic framework analysis: LLMW, LLW, TRUW, and HW. For purposes of the PEIS analysis, HLW, also in the above treatability categories, is assumed to have been treated (vitrified). The PEIS only addresses the environmental consequences of storing and transporting vitrified HLW.

Radiological and Chemical Composition. DOE used standard radiological profiles for each site and made assumptions about the concentration of contaminants in each treatability group based on available data. Hazardous constituents were apportioned to the treatability groups on the basis of the most prevalent hazardous chemicals using an average composition for all DOE sites. The assumptions for both radioactive and hazardous constituents are waste-type specific and are addressed in more detail in the waste-type chapters.

C.2.2 WM TECHNOLOGIES

Various technologies are used to sort and handle waste, reduce waste volume, destroy organic chemicals in waste, remove toxic metals from waste, treat hazardous characteristics to render them nonhazardous, recover and recycle materials, and stabilize and package waste for disposal. The facilities that use these technologies must be designed to accommodate the various physical and chemical forms and the radioactive and chemical characteristics discussed in previous sections. Existing, generic technologies necessary to meet

the treatment, storage, and disposal requirements for each waste type were identified and sized to meet anticipated waste volume needs. For analytical purposes, and to facilitate utilization in any system at any site, the waste management technologies were grouped into **common functions** (front-end support such as administrative and laboratory services; receiving, inspecting, dumping, and sorting the waste; maintenance of facilities; and certification and shipping of the waste), **pretreatment** (shredding and compaction), **primary treatment** (incineration, special processing, neutralization, deactivation, aqueous waste treatment, lead recovery, and mercury separation and recovery), **secondary treatment and stabilization** (polymer stabilization, grout stabilization, packaging, and vitrification of secondary processing residues), **storage** (administration, receiving and inspection, contact-handled storage, and remote-handled silo storage), and **disposal** (administration, receiving and inspection, shallow land disposal, engineered vault disposal, silo disposal, and borehole disposal). The technologies used in the WM PEIS were chosen for analytical purposes only; the Records of Decision based on the WM PEIS will not select technologies.

Existing, rather than advanced, technologies were used for the analysis because (1) the applicability of advanced technologies is more problematic, (2) impacts would more likely be bounded using existing technologies, and (3) the type of technology would be unlikely to determine the preferred alternative. However, advanced technologies will be considered in project-specific National Environmental Policy Act (NEPA) reviews expected to tier off from this programmatic review.

C.2.3 WM FACILITIES

Treatment, transportation, storage, and disposal "modules" were developed to represent every component required for waste management. Each module was assumed to contain several types of equipment, each able to perform a step needed in the waste management process.

Individual modules were linked together for each treatability group and were adjusted for the chemical and physical type of waste. This method was used so that impacts could be compared among sites, with each site assumed to be using the identical array of linked modules. Any variation in impacts would then result from site-specific environmental differences. This approach also allowed an examination of the changes in impacts resulting from changes in the linked modules.

Typically the type of facility considered was a building structure (i.e., a "fixed" facility at a given site). The analysis also considered the possible use of mobile treatment facilities that could be moved from site to site for treatment of the very small amounts of waste that exist at a number of the sites considered.

The generic design of the WM facility, consisting of these treatment, storage, transportation, and disposal modules, enabled the calculation of land utilization, worker-years, resource consumption (i.e., water and electricity), pollutant discharges, and costs for the treatment, storage, transportation, and disposal of each waste type. The engineering features of the generic facility and the waste loads "processed" through the generic facility formed the basis for the risk and environmental impacts analysis.

For purposes of analysis, the following assumptions were made regarding the construction and operation of the waste management facilities:

- The facilities were assumed to be built over a 10-year period and operated over a 10-year period to process inventories accumulated over a 20-year period. This was the basic assumption for LLW, LLMW, TRUW, and HW. This assumption was made prior to the analysis of facility costs required for the treatment, storage, and disposal of the various wastes. This assumption of similar operating conditions was made in order to allow the possible consolidation of facilities. Consolidation was not required in the PEIS, but would be attempted when facility requirements were being reviewed for justification of facility construction or for site-specific EISs.
- The facilities were assumed to operate 240 days per year with three 8-hour shifts.
- Except for HLW, a 20-year period of analysis is generally used for each waste type. Storage requirements for HLW under the No Action Alternative were assumed to be indeterminate in length, but in excess of this 20-year period. For this analysis, 30 years was assumed to be the longest period for which reasonable estimates of the HLW No Action Alternative could be made.

Although the WM PEIS only analyzes the environmental impacts from the operation of the WM facilities for 10 years, it is possible that the facilities could operate for up to 30 years. During this additional 20-year operating period, additional WM wastes or ER wastes could be processed. DOE believes that most of the impacts of operating the WM facilities for an additional 20 years would be similar to the impacts of operating these facilities for the 10 years analyzed in the WM PEIS. DOE believes this for the following reasons:

- The 10-year period of operations analyzed in the WM PEIS includes processing wastes accumulated for 20 years (i.e., waste accumulated during 10 years of construction and 10 years of operations) in

addition to any wastes in storage. Therefore the feed rate into the WM facilities would be expected to bound the feed rate during the latter 20 years of operations.

- Many of the impacts analyzed in the WM PEIS were analyzed on a daily or annual basis. For example, infrastructure impacts were analyzed for resource use in gallons of water per day, gallons of wastewater per day, and megawatts of power per year. Resource use during operation of the facilities for an additional 20 years is unlikely to exceed these rates of resource use and therefore is unlikely to exceed the environmental impacts predicted in the WM PEIS.
- Some impacts in the WM PEIS, such as human health risk to the offsite population, were analyzed for the entire 10-year operations period. DOE expects that the impacts during the additional 20 years of operations would be no more than twice the impacts predicted in the WM PEIS. For example, if the WM PEIS predicted a population health risk of 1 in 1 million (see Chapters 6 through 11 for actual risk estimates), the additional health risk of operating the facilities for 20 more years would be no more than 2 in 1 million, with a total health risk for 30 years of operations of 3 in 1 million.

This assumes that the characteristics of the waste processed during the additional 20-year operating period are similar to the characteristics of the wastes analyzed in the WM PEIS. If the characteristics of the wastes processed during the latter 20 years of operations are found in the future to be appreciably different from the characteristics of the waste analyzed in the WM PEIS, additional environmental documentation could be prepared to support continued operations.

C.2.4 ALTERNATIVES

In the PEIS, an alternative identifies the configuration of sites for treating, storing, or disposing of a specific waste type. Depending on the waste type, certain of these activities may not be analyzed in this PEIS. The categories of alternatives analyzed in this PEIS for each waste type are a No Action Alternative, Decentralized Alternative, Regionalized Alternative, and Centralized Alternative. These alternatives are described below:

- **No Action Alternative**—These alternatives would involve using only currently existing or approved WM facilities at DOE sites or commercial vendors.
- **Decentralized Alternative**—These alternatives would result in leaving waste at the site where it is currently stored or where it will be generated, treated, or disposed in the future. Unlike the No Action alternatives, the Decentralized Alternatives may require the siting, construction, and operation of new

facilities or the modification of existing facilities. Under the Decentralized Alternatives, the WM facilities would be located at a larger number of sites than under the Regionalized or Centralized Alternatives.

- **Regionalized Alternatives**—These alternatives would result in transporting waste to various numbers of sites (fewer than the number of sites considered for the Decentralized Alternative, but greater than the number of sites considered for the Centralized Alternatives). Generally, those sites that now have the largest volumes of a given waste type were considered as regional sites for treatment, storage, or disposal.
- **Centralized Alternative**—These alternatives would result in transporting wastes to one or two sites for treatment, storage, or disposal. As was the case with the Regionalized Alternatives, the sites that have the largest volumes of a given waste type were considered as sites for centralized treatment, storage, or disposal.

These four categories of alternatives encompass the range of reasonable alternatives available to DOE for siting of WM facilities. However, under each category of alternative, there are many possible combinations for the location of treatment, storage, and disposal facilities. To narrow these combinations to a feasible number for analysis, DOE selected particular site combinations for analysis under each category.

The alternatives were developed and defined based on waste type origin and character, volumes and locations within the DOE complex, existing facilities and capabilities, and specialized treatment and disposal requirements. DOE determined where the largest waste volumes are located and where transportation requirements would be minimized. Treatment, storage, or disposal facilities were analyzed at those sites. For example, if seven sites were to be considered under a Regionalized Alternative, then the seven sites with the largest volume of that type of waste became candidate sites for the analysis. Another Regionalized Alternative for the waste type being analyzed may evaluate management at three sites; in that situation, the three sites with the largest volume of that type of waste were considered as candidate sites. Existing capacity, transportation, and other factors were also considered in developing alternatives. As shown in Table C.2-1, a combined total of 36 alternatives were evaluated for the five waste types. The waste-type chapters (Chapters 6-10) contain more information on the alternatives analyzed in the WM PEIS.

Table C.2-1. Number of Alternatives Analyzed in the PEIS

Alternatives	LLMW	LLW	TRUW	HLW[a]	HW	Total
No Action	1	1	1	1	1	5
Decentralized	1	1	1	1	1	5
Regionalized	4	7	3	2	2	18
Centralized	1	5	1	1	0	8
Total	7	14	6	5	4	36

[a] HLW alternatives are analyzed in terms of both final disposal beginning in 2015 and final disposal beginning at some later date.

C.2.5 TRANSPORTATION

Transportation is an integral component of the alternatives being considered for the management of each type of waste in the PEIS. The magnitude of the transportation related activities varies with each alternative, ranging from minimal transportation under the Decentralized Alternatives to significant transportation under some of the Centralized Alernatives.

The transportation assessment included the onsite and offsite transportation of radioactive waste. Offsite transportation refers to transporting waste between distinct sites, including parts of the routes that may be within the boundaries of the origin and destination sites. Onsite transportation was evaluated for one sample site: Hanford.

The transportation linkages among generator, treatment, and disposal sites depend on the type of waste and are defined explicitly for each alternative under consideration. For the PEIS, representative offsite truck and rail routes were determined for all possible pairs of origin and destination sites. The routes were selected to be consistent with existing routing practices and all applicable routing regulations and guidelines.

The representative truck routes were determined by using the routing model HIGHWAY 3.1 (ORNL, 1993a). INTERLINE 5.0 (ORNL, 1993b) was used to determine the rail routes. For truck and rail transportation, the route characteristics most important to the assessment included the total shipping distance between each origin and destination pair and the fraction of travel in rural, suburban, and urban areas. Because the routes were determined for the purposes of impact assessment, they are not simply representative of the actual routes that would be used to transport waste in the future.

For the offsite transportation assessment, each specific alternative is defined as a set of pairs (origin and destination) representing shipping linkages among generator, treatment, and disposal sites. The number of origin-destination pairs varies among alternatives, ranging from a small number for the Decentralized Alternatives, to many pairs for the Centralized Alternatives. The sites that would not have the capability to dispose of wastes would ship their wastes to a sites that does. Appendix E contains more detailed information on the transportation analysis.

C.3 Phase II: Engineering Analysis Outputs

The engineering features of the generic facility and the waste loads "processed" through the facility formed the basis for the estimates of resources required, effluents released, and cost. The resources required and effluents emitted were used to estimate environmental impacts from construction and operation of the WM facilities.

Resource Use. The Waste Management Facility Cost Information (WMFCI) methodology model was used to estimate the resources required for construction and operations of each WM facility. The resources included labor (number of FTEs), land, water, electrical energy, fuel (natural gas, diesel oil, and coal), chemicals, concrete, carbon steel, and stainless steel. A description of the engineering analysis used to estimate the resources used is provided in this section.

Facility Environmental Discharges. Once the generic designs and the volumes and characteristics of the waste and the model throughput requirements were specified, the WASTE_MGMT model was used to estimate discharges from the treatment, storage, and disposal modules (Argonne National Laboratory [ANL], 1996c). DOE estimated the radiological and chemical components in air and water effluents from processing the waste, and the chemical components in air effluents from the burning of fuel during the operations period. Section C.4.2 of this Appendix identifies the airborne emissions used in the analysis of air quality impacts. Discharges were assumed to be 90% from point sources and 10% from fugitive releases (ANL, 1996c). Section C.4.3 provides the estimates of releases from LLMW and LLW disposal units into groundwater that were used in evaluating water quality impacts.

Facility and Transportation Costs. The WMFCI methodology was also used to estimate life-cycle facility costs. Total cost of each alternative include the sum of the treatment, storage, disposal, and transportation costs, and in some instances, special costs. Examples of special costs include the Oak Ridge Reservation

"B&C Pond sludge" treatment and disposal actions. Section C.3.2 describes the details of the engineering cost estimation procedures.

C.3.1 RESOURCE USE

The resource use data-estimating process for LLMW, LLW, TRUW, and HW (part of the WMFCI methodology) used the mass/volume throughput to quantify resource consumption for each WM module. Supplemental methodologies provided resource estimates for modular throughputs which were bounded by WMFCI estimates. Samples of tabular presentations of resource use data accompany the discussions. Tabular details are provided (INEL, 1996). The resource use data-estimating process for HLW used regression formulas developed by ANL (ANL, 1996b).

C.3.1.1 Modular Estimating Approach

The resource consumption estimated for each module was dictated by a series of allocation rules. These rules were applied to each module to obtain resource quantities for the module size selected. The resource categories were selected before the actual analysis of any alternatives. During the impacts analysis process, it was determined that several resource categories were not directly needed in the analysis. However, the allocation rules for resources for all facilities are discussed.

C.3.1.1.1 *Construction Resource Use*

The following assumptions were common to developing the resource use parameters for construction activities.

A construction year was defined as 252 workdays, thus allowing time for holidays and weekends. Each workweek is assumed to be 40 hours and composed of five 8-hour days. An FTE (full-time equivalent) employee represents one person working full-time for one construction year, one shift per day.

Most modules were assigned a 2-year construction period, representing the total time assumed from the startup to end of construction activity. A 3-year period was assigned to modules requiring installation of

more complex equipment or special construction. The time needed to construct each module was included in tables in the resource use computer code. It was assumed that multiple modules will be placed within a single building. The time required to finish the entire plant is controlled by the interface requirements and staggered delivery schedules normally experienced during construction of a multipurpose facility. On any given site, construction of all required modules was assumed to take three to four years.

Many of the resource use parameters for construction were based on an estimate derived for construction of a generic treatment plant. A 120,000-square-foot generic plant and 3-year construction period were assumed (INEL, 1994).

The module area was a key parameter used in calculating the construction material quantities required. In the construction data tables of the resource use computer program, each construction material quantity is specified in terms of units per square foot. The area was used as a multiplier to calculate the total construction material quantities. The module area was determined from the plant area calculation presented later in this section. All buildings were assumed to be rectangular with a length-to-width ratio of 4:1.

Additional allocation rules for construction socioeconomic resource data included electrical energy, electrical load, fuel, water, laydown area, plant area, parking area, peak employment, and annual costs. Allocation rules for concrete, carbon steel, stainless steel, chemicals, and type of skills which were not used in evaluating environmental impacts are presented in the Environmental Impacts Technical Report (DOE, 1996a).

The resource use parameters for construction are as follows.

Electrical Energy (in megawatt-hours). This value represents the total amount of electrical energy consumed during construction.

Estimate Basis: Electrical energy was calculated by multiplying the connected electrical load, by the hours of use. The hours of use were based on a standard construction year (252 days). The average capacity was assumed to be 65%, which was determined by estimating the electrical energy consumed for construction of the generic treatment facility described above.

The typical allocation of electrical energy during construction was assumed to be 0.017 kilowatts per square foot for all types of facility modules.

Electrical Load (in kilowatts). This is an estimate of the connected electrical sources required during construction.

Estimate Basis: The electrical load factors for treatment and administration modules were based on the estimates developed for the generic treatment facility described above. The electrical load factor for each module was calculated in kilowatts per square foot of plant area. Total electrical load was obtained by multiplying the module area by 0.017 kilowatts per square foot for all types of facility modules.

Disposal modules with significantly less construction activity, such as the above-ground disposal module (AGDSP), silo disposal module (SIDSP), and silo storage module (STOSI), had an electrical load factor assumed to be approximately 20% of that of treatment modules. Modules such as shallow land disposal module (SLDSP), which do not include a plant with concrete and metal works, were assumed to have an electrical load factor of only 8%. Borehole disposal (BHDSP) was assumed to be constructed without electricity.

Fuel (in gallons). Fuel oil, gasoline, and propane are included in this parameter. In addition, an allowance of 840 gallons per FTE was assumed to account for fuel used by each employee on the job site and fuel required for travel to and from work.

Estimate Basis: The fuel factor for construction equipment was based on the fuel consumption estimate for the generic treatment facility described above. A consumption rate in gallons per square foot of plant area per year of construction was derived. A significantly lower value was estimated for the disposal modules. The fuel consumed by construction equipment for each module was obtained by multiplying by the module's area. Fuel consumption during construction for all modules was computed as the module area times 2.35 gallons per square foot of area.

Fuel consumption by construction employees was estimated by assuming that the workers will travel a 50-mile round trip to the construction site each day of a construction year. A fuel consumption rate of 15 miles per gallon was assumed. This gives 840 gallons per workyear (FTE) for all modules.

Water (in gallons). Estimates for water use include the water consumed during construction activities, potable water consumed by employees, and process water.

Estimate Basis: The estimate for the amount of water consumed during construction was based on the generic treatment facility estimate described above. The average use of water for dust control, equipment washdown, concrete water, and general cleaning of work areas was determined on a per square foot of plant area basis. A value equal to half of this estimate was used for all disposal and storage modules, based on the fact that fewer construction activities are included with these modules. Total water used for these activities was obtained by multiplying the quantity needed per square foot by the module's area.

The generic treatment facility estimate was also used to derive the amount of water used by a construction worker per year. The resulting yearly water usage factor was 3,400 gallons per FTE. General construction requirements were 27.5 gallons per square foot of area per year for all modules.

Laydown Area (in acres). The construction laydown area includes the area for each plant module plus that used for equipment and material storage.

Estimate Basis: The laydown area was estimated by adding a 25-foot-wide buffer to all four sides of the area required for each module. The laydown area for the site was obtained by adding the laydown areas for all modules composing the facility. A length-to-width ratio of 4:1 was assumed for all modules and the buildings containing the modules. The plant area was taken from the calculation below.

Plant Area (in acres). The plant area was obtained by summing the area requirements of the individual modules that constitute the facility. Each module's area was obtained by utilizing a relationship that relates the space required to the module's throughput capacity.

Estimate Basis: Three different module sizes were used to baseline the cost rollup and resource use data for most modules. Only two were used in a limited number of cases. The area required by any module was obtained by calculating a regression curve relating the three baseline sizes to their throughput capacity. The area needed for any other module was then obtained from this curve, based on the throughput capacity of the module in question. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

Parking Area (in acres). The parking area was obtained by allocating 400 square feet of space to 85% of the number of workers constituting peak employment.

Estimate Basis: A total individual parking area of 400 square feet was assumed, which includes space for both parking and maneuvering. The number of parking spaces required was based on the peak number of FTEs needed for construction. Parking space was assigned to 85% of this number, assuming that 15% will carpool. Unload/offload was assumed to take place in the laydown area.

Peak Employment (in FTEs). Peak employment is defined as the maximum number of construction employees that will be on the site on any workday during the entire construction period.

Estimate Basis: The total number of construction FTEs was obtained from the cost rollup data. The total number of FTEs divided by the construction period (in years) provided the average annual FTEs. Peak employment was estimated as 1.41 (i.e., the square root of 2) times the average number of FTEs per year.

Annual Costs (in $\times$1,000). Each of the various average annual construction cost items is divided among labor, material, or equipment categories.

Estimate Basis: The percentage of labor, materials, and equipment involved in the cost item breakdown was based on previously designed and constructed structures involving similar facilities. This cost information was taken from the cost rollup data.

C.3.1.1.2 *Operations Socioeconomic Resource Use*

The following assumptions were common to developing resource use parameters for facility operations.

An FTE employee represented one person working one shift per day for 252 days per year. Yearly plant operation was taken to be 4,032 hours assuming three 8-hour shifts daily, 240 days per year, with the plant available 70% of the time. The difference between an FTE-year and an operational year allows for the time when an employee may be working but the facility is not operating.

All socioeconomic parameters given for facility operations were annualized.

The module area were also an important factor in calculating operational resource use data. The calculation for module area used in this section is the same as that employed in the construction section.

Additional allocation rules for operations socioeconomic resource data include the following for electrical energy; electrical load; fuel, natural gas or liquid propane gas; fuel, liquid; water; total disturbed area; plant area; total number of worker years; hours per week for labor; operation and maintenance (O&M) labor; operations costs; and maintenance costs.

The resource use parameters for facility operations are as follows.

Electrical Energy (in megawatt-hours). This value represents the total electrical energy consumed during plant operations for one year.

Estimate Basis: Electrical energy was calculated by multiplying the connected electrical load by the hours of use. It was assumed that the equipment will operate half the time the plant is available. The "hotel load" (i.e., the electricity required for people), in watts per square foot, was multiplied by the module area (from below). Both were multiplied by the hours of use per year. The plant is assumed to operate 4,032 hours per year. This assumes three shifts per day, 240 days per year, with the module available 70% of the time.

Electrical Load (in kilowatts). This value represents the connected electrical load expressed in kilowatts. It was based on the electrical requirements of the equipment in the module plus the hotel load (i.e., the electrical load needed to support human occupancy). The hotel load includes lights, wall plugs, and where appropriate, air conditioning.

Estimate Basis: The resource use computer code contains estimates for the horsepower requirements of the equipment in the middle (or small) baseline facility. This was converted into watts and multiplied by the ratio of the module's throughput capacity to that of the baseline facility. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

The code also contains estimates of the hotel load in watts per square foot for each module. The hotel load was multiplied by the module's area and converted to kilowatts. Estimates of the hotel loads for the

processing, storage, and administrative modules were based on supporting technical documentation (INEL, 1996).

Fuel, Natural Gas or Liquid Propane Gas (in pounds). This value represents the fuel needed to heat the building for one year, assumed to be natural gas.

Estimate Basis: This estimate was based on supporting technical documentation (INEL, 1996). The calculation assumed that to heat the module for the entire winter, the furnace runs an equivalent of 2 months, 24 hours per day. It was further assumed that 3 British thermal units (BTUs) are needed to heat 1 cubic foot of volume for one hour. Multiplying the module volume by 3 BTUs/hour by 1440 hours yielded the total heat required. One cubic foot of natural gas equals 1,030 BTUs.

Fuel, Liquid (in gallons). This quantity represents the fuel required to operate specific pieces of process equipment for one year. Where required, it accounted for operating the equipment at full power as well as maintaining equipment in a hot standby condition. The fuel assumed for these calculations was standard diesel oil.

Estimate Basis: Some of the modules that process waste require fuel to operate. For those modules, the quantity of fuel required was calculated from the throughput capacity. Tables in the resource use computer program give the quantity needed for each 100 pounds of waste processed. The amount of fuel calculated from the throughput capacity per hour was then multiplied by the hours of operation per year.

In addition to the fuel needed to process waste, fuel is needed to keep the equipment in a hot standby condition. It was estimated that 75% of the amount needed for operation is required during the hours per year the plant is available. The plant was assumed to operate 4,032 hours per year, three shifts per day, 240 days per year, with the module available 70% of the time.

Water (in gallons). When required, water needed for operating process equipment was calculated specifically for the module in question. In addition, the quantities of water used and consumed by O&M employees were estimated. These were summed to derive the total water used per year.

Estimate Basis: Some of the modules that process waste utilize water. For those modules, the quantity of water required was calculated from the throughput capacity. Tables in the resource use computer program

give the quantity needed for each 100 pounds of waste processed. The amount of water calculated from the throughput capacity per hour was then multiplied by the hours of operation. The plant was assumed to operate 4,032 hours per year, three shifts per day, 240 days per year, with the module available 70% of the time.

Aqueous waste treatment was assumed to generate 86.7 pounds of water per hour for every 100 pounds of waste mass processed per hour. Incineration was assumed to use 109 pounds of water per hour, grouting 26.1 pounds of water per hour, and mercury recovery 10 pounds of water per hour.

Each FTE was assumed to use 20 gallons of water per day. The operating year for water use was taken as 252 days. The total water used was the sum of that used by the processing equipment and that used by the O&M personnel.

Total Disturbed Area (in acres). The disturbed area required for an individual module was assumed to encompass a space with sides 10 feet from the area needed for processing or other activities. The module was assumed to be rectangular with sides in a ratio of 4:1. The disturbed areas for each module were summed and the area of the parking lot added to yield the total disturbed area for the plant.

Plant Area (in acres). For each module, this value represents only the area needed for conducting the stated operation. The total facility area is a simple sum of the individual module areas that make up the facility.

Estimate Basis: Three different module sizes were used to baseline the cost rollup and resource use data for most modules. Only two sizes were used in a limited number of cases. The area required by any module can be obtained by calculating a regression curve relating the three baseline sizes to their throughput capacity. The area needed for any other module was then obtained from this curve, based on the throughput capacity of the module in question. A scaling factor was applied in instances where the throughput capacity of the module in question was outside the range of the baseline facilities.

Parking Area (in acres). Parking space was assigned to each FTE. Visitor parking was accounted for by assuming 15% of the FTEs will carpool. Unload/offload parking was assumed to be included within the plant area.

Estimate Basis: The number of FTEs was obtained from the cost rollup data by dividing the total number of O&M FTEs by the number of operating years. A total of 400 square feet was assigned to each FTE. This total included both parking area and maneuvering room.

Total Number of Worker Years (in FTEs). This value, in FTEs, was taken from the cost rollup data. An FTE represented one person working an 8-hour shift for 1 year composed of 252 days.

Hours per Week for Labor (in hours). A total of 40 hours was assumed.

Operating Labor (as a percentage of total skills). This value was taken as the total labor pool (i.e., the total number of O&M FTEs) less the number required for maintenance.

Estimate Basis: The average annual number of FTEs needed for both operations and maintenance was obtained from the cost rollup data. This number is equal to the total number of O&M FTEs divided by the number of operating years assumed for each module. The percentage of FTEs used for operating labor was obtained as follows: First, maintenance labor cost was calculated based on the equipment cost (see below). Next, the number of annual FTE maintenance employees was obtained by assuming each worker has an expense of $140,000 per year. The annual number of FTE operating personnel was obtained by subtracting the number needed for maintenance from the total average annual number of O&M FTEs. The ratio of annual operating FTEs to the total annual average O&M FTEs yielded a percentage.

Maintenance Labor (as a percentage of total skills). Annual maintenance labor was assumed to be equal to a percentage of the equipment cost plus a contingency factor. Equipment costs were obtained from the cost rollup data.

Estimate Basis: The annual number of maintenance FTEs was calculated as follows. First, the maintenance costs for labor were estimated by assuming that the labor costs are equal to 250% of the maintenance material costs for each module. The maintenance material costs were taken as a percentage of the equipment cost (between 3% and 7% depending on the module). By assuming each FTE cost was $140,000 per year, the total number of maintenance FTEs was calculated. The ratio of annual maintenance FTEs to the total annual average O&M FTEs yielded a percentage.

Maintenance ($\times$1,000). Annual maintenance costs were composed of two factors, material and labor. These values were estimated as a percentage of the cost of the equipment.

Estimate Basis: Maintenance cost was based on the equipment cost. It is assumed that 3% to 7% of the equipment cost was spent annually for maintenance materials, and the cost of maintenance labor is 2.5 times the material costs. To derive the total maintenance cost, a 25% contingency factor was added to this sum.

Operations ($\times$1,000). Operating costs constitute all costs needed except those required for maintenance.

Estimate Basis: The total annual cost of O&M was obtained from the cost rollup analysis. The annual cost was obtained by dividing the total cost by the number of operating years assumed for each module. The number of operating years was also obtained from the cost rollup data. The annual cost of operations was obtained by subtracting the maintenance costs (from above) from the annual O&M cost.

C.3.1.2 Resources Associated With Portable Modules

Small generator sites typically generate very small quantities of certain wastes. Where portable modules were used (TRUW and LLMW), resource consumption was identified for each portable module and its contribution was rolled up into the site resource totals.

C.3.1.3 Resource Data Estimate Methodologies for WM PEIS Alternatives

To analyze resources, the PEIS waste volume data were first divided into four waste types: LLW, LLMW, TRUW, and HW. These waste types were then subdivided into cases to analyze the alternatives. The cases were subdivided according to handling characteristics, sites, and construction or operations activities. Generic technology modules were identified and sized to meet the treatment, storage, and disposal requirements for each case. Resource data results were compiled for each alternative by summing the various resource data components for each module, then summing the module results for each site (DOE, 1996a).

For some alternatives, supplementary extrapolation methodologies were applied. The data for these alternatives were obtained from similar data computed as described in Sections 3.1.1–3.1.3, then scaled

based on either cost or waste processing rates. The supplemental resource methodologies used for LLW, LLMW, TRUW, and HW can be found in *Waste Management Environmental and Socioeconomic Impacts Methods and Results* (DOE, 1996a).

C.3.2 COST ESTIMATING

Costs were estimated using an approach that tied the cost of facilities and transportation to waste quantities. In addition, DOE used costs associated with existing technologies and historical industrial cost experience for estimating purposes.

C.3.2.1 Cost-Estimating Process Details

Each alternative includes a definition of the assumed technologies for the complete treatment process. For each site and each alternative, wastes were hypothetically routed through the waste management process, and the modules were individually sized to handled the processing requirements. Since many sites have existing treatment, storage, and disposal capabilities (INEL, 1994), the analyses accounts for existing facilities to minimize additional construction requirements. However, only O&M costs were estimated for existing facilities.

C.3.2.1.1 *Waste Management Facility Cost Information Reports*

The PEIS used a set of reports, collectively referred to as the "WMFCI reports," to develop cost and manpower estimates for the various alternatives and cases being considered. These reports were prepared for DOE by EG&G Idaho to provide a generic facility costing and resource use estimating methodology for programmatic analysis of treatment, storage, disposal, and inter-site transportation of radioactive and hazardous waste. The WMFCI reports consist of the following:

- Data extracts of the detailed facility equipment and construction estimates and other costing factors applied to base estimates for waste types
- Management analysis reports summarizing the findings of the data extract reports according to waste type

- Procedural reports that describe how to compute costs and manpower for the modules used for the treatment, storage, and disposal of waste types
- Data reports computed by PEIS alternative/case by waste type for cost and FTEs, and for resource consumption data supporting the environmental impacts analysis

The WMFCI reports provide a consistent and defensible basis for generating life-cycle cost information for treatment, storage, and disposal facilities using specific data for each major waste type. The WMFCI reports present cost and manpower information reports for LLMW, LLW, TRUW, and HW (INEL, 1995a-d). Within the waste-type categories listed above, cost information was developed for alpha-contaminated wastes (both LLW and LLMW) and remote-handled (RH) waste (LLW and TRUW). For some treatment processes, costs for portable systems were developed for non-alpha contaminated waste (LLW and LLMW); these were deemed more realistic and lower cost approach for treating extremely small waste loads. A separate report (INEL, 1995e) was developed to provide a cost computation methodology applicable to the shipment and routing information provided in Appendix E for the transportation of radioactive and hazardous wastes. A full listing of WMFCI reports is provided in the references cited section of this appendix.

The WMFCI reports were developed specifically for DOE-owned facilities. The cost-estimating used in the reports included provisions necessary to comply with all applicable regulatory requirements for a particular waste type and to meet the requirements of all applicable DOE orders. Indirect costs and overhead burden rates used in the WMFCI reports were based on those historically encountered at DOE's Idaho National Engineering Laboratory (INEL), which fall approximately in the middle of the range of cost factors found at several other DOE sites and which are, therefore, considered to be representative for complex-wide estimating purposes.

C.3.2.1.2 *Modular Estimating Approach*

To facilitate the development of comprehensive cost estimates covering cradle-to-grave management of wastes, the WMFCI reports categorized all necessary WM activities into a series of modules, each representing a discrete facility that carries out a single WM function. A unique set of cost information was developed for each WMFCI module (see Table C.3–1). Within a given module, a series of unit operations necessary to accomplish the specified function was defined in sufficient detail to enable development of the

Table C.3–1. Facility Cost Modules Included in WMFCI Reports[a]

Module	LLW	LLMW	TRUW	HW
Treatment Front-end Support	x	x	x	x
Small Generator Front-End/Back-End Support	x	x		
Waste Characterization			x	
Packaging	x	x	x	
Stored Waste Retrieval			x	
Receiving and Inspection	x	x	x	x
Open, Dump, and Sort	x	x	x	
Assay, Sort, and Package				x
Maintenance	x	x	x	
Incineration	x	x	x	x
Aqueous Waste Treatment		x	x	x
Neutralization	x		x	
Shredding/Compaction	x	x	x	
Supercompaction	x			
Metal Melting	x	x		
Wet-Air Oxidation		x		
Thermal Desorption		x		
Debris Washing		x		
Soil Washing		x		
Lead Recovery		x	x	
Mercury Separation		x	x	x
Organic Removal				x
Deactivation		x	x	x
Special Waste Processing	x	x	x	
Recycling				x
Organic Stabilization			x	
Grout Stabilization	x	x	x	x
Polymer Stabilization	x	x		
Vitrification	x	x	x	
Certification and Shipping	x	x	x	x
Storage Front-end and Back-end Support	x	x	x	
Storage Receiving and Shipping			x	
Storage	x	x	x	
Silo Storage	x		x	
Disposal Front-end Support	x	x		
Engineered Disposal	x	x		
Shallow Land Disposal	x	x		x
Silo Disposal	x	x		
Borehole Disposal	x	x		

[a] HLW facilities are covered in a separate report (ANL, 1996b) but included only storage facilities.

planning level cost information. For example, the incineration module included each of the following unit operations: feed preparation, incineration, secondary combustion, and off-gas treatment. The array of unit operations is sufficiently broad to accomplish the incineration tasks required by the identified waste inventories.

Once a particular WM alternative-based scenario was defined, a series of modules was selected that best represented all activities required to accomplish the necessary WM functions. Some scenarios may have required only 1 or 2 modules to fully define the WM functions, while others may have required 10 or more modules to capture all necessary functions. This modular approach to establishing the cost-estimating basis provided maximum flexibility; thus, the WMFCI was designed to be the full used to support a broad range of WM options.

Design of the WMFCI was based on standard, proven technologies and WM approaches. The modules represent a variety of treatment, storage, disposal, material handling, and support facilities, that were developed for all major DOE waste streams. The cost modules, are listed by waste type in tables found in (INEL, 1996).

Facility costs were established on the basis of the costs of DOE facilities (primarily at INEL) and commercial facilities. To the extent possible, equipment costs for each facility module were compared with data from anchor facilities to establish a cost confidence level with the boundaries established for programmatic life-cycle cost estimates. Both DOE and the commercial nuclear industry are now planning or operating similar facilities. These facilities were surveyed to obtain capacity and cost data and other information needed to support the cost methodology data. Before using these costs, the data were adjusted to account for capacity differences and escalation.

Additional assessment activities included a review of existing DOE facility capital and operating costs for comparison with the cost methodology data. Existing DOE facilities that have been evaluated include the Waste Experimental Reduction Facility (incineration, shredding, and compaction) at INEL; the Controlled Air Incinerator at Los Alamos National Laboratory; the Toxic Substances Control Act (TSCA) Incinerator at Oak Ridge Reservation; the Supercompactor and Repackaging Facility at Rocky Flats Environmental Technology Center; the Radioactive Waste Management Complex (LLW disposal) at INEL; and the Transportable Waste Water Treatment Unit from the Uranium Mill Tailings Remedial Action Project. Planned DOE facility costs at INEL were also evaluated for the Radioactive Waste Storage Facility, the

Waste Characterization Facility, the Idaho Waste Processing Facility, and the Mixed Low-Level Waste Treatment Facility.

Other facilities evaluated include the Illinois Compact Low-Level Engineered Disposal Facility and the Commonwealth of Massachusetts Low-Level Radioactive Waste Disposal Facility.

Cost estimates for facility components were adapted from commercial sources (INEL, 1995b-d, 1996). Commercial facilities evaluated include conceptual designs and cost estimates for air- and area-monitoring units from Eberline Corporation of Santa Fe, New Mexico; amalgam mixers from Miracle Paint Rejuvenator of St. Paul, Minnesota; blending equipment from Velmac Associates, Inc., of Novato, California; calciner/kiln units from ABB Raymond, Inc., of Lisle, Illinois; chemical oxidation units from Peroxidation System, Inc., of Tucson, Arizona; compactor units from Stock Equipment Company of Chagrin Falls, Ohio; concentrator units from LCI Corporation of Charlotte, North Carolina; drum capping and washing units from Stock Equipment Company of Chagrin Falls, Ohio; dry off-gas filters from Pall Advances Separation Systems of Cortland, New York; dry and wet off-gas treatment trains from NGK-Locke, Inc., and Callidus Technologies; drying equipment from Wyssmont Co., Inc., of Fort Lee, New Jersey; extruder equipment from Sterling Extruders, Davis-Standard Division of Edison, New Jersey; gross-organic removal units from McTighe Industries, Inc., of Mitchell, South Dakota; incineration packages from Joy Energy Systems of Charlotte, North Carolina, and ABB Raymond, Inc., of Lisle, Illinois; quencher and scrubber (wet scrubbing) units from Croll-Reynold Company of Westfield, New Jersey; melter units from Ajax Corporation and Retec Corporation; preparation and feed units from various vendor quotes; processing equipment from the U.S. Navy LLW processing facility of Lynchburg, Virginia; open, dump, and sort devices and robotic arms in consultation with personnel from DOE contractors involved with the Office of Technology Development, Robotic Technology Development Program; organic stripper units from APV Crepaco, Inc., of Tonawanda, New York; radiological and hazardous material measurement systems from conceptual designs and cost estimates provided by Lockheed-Martin; segmented gamma scanning (SGS) assay systems data from Atlan-Tech Corporation, Inc., of Roswell, Georgia; shredder units from Komor Industries, Inc., of Groveport, Ohio; feeder/shredder units from System Service Solutions of Wilsonville, Ohio; retort units from Denver Mineral Engineers, Inc., of Littleton, Colorado; size reduction and baler systems from Stock Equipment Company of Chagrin Falls, Ohio; selected solidification units from Stock Equipment Company; solidification module assemblies from Stock Equipment Company; stack monitoring units from Eberline Corporation of Santa Fe, New Mexico; suspended-solids filtration systems (Membralox) from U.S. Filter Corporation of Warrendale,

Pennsylvania; thin-film evaporator units from LCI Corporation of Charlotte, North Carolina; washing equipment from CF Systems (a subsidiary of Morrisen-Knudson); wet oxidation units from Zimpro of Rothchild, Wisconsin; and the commercial treatment and disposal processes for hazardous wastes from various vendors (INEL, 1995a-d).

C.3.2.1.3 *Cost-Estimating Basis*

A "bottom-up" estimating approach was used to develop the WMFCI unit costs. Initially, a capacity range for each facility cost module was established by studying the currently stored and future projections of DOE waste volumes. Process functional diagrams and facility layout drawings were developed at the individual unit operation level. After all unit operations required for a module were defined, major equipment lists, building configurations, and square footage requirements were established, and cost estimates for each facility were developed.

Data from the study defined baseline capacities for five facility sizes: portable, minimum-fixed, small, medium, and large. Using the five facility sizes, a generic design package for each cost module was developed and used as the basis for the Program Life Cycle Cost (PLCC) estimates. Each design package included a summary functional and operational requirements description, a process functional diagram with mass flow rates, a facility layout, manpower requirements for the processes, and cost and manpower (FTE) capacity-to-requirement curves. The design packages used as much available data from existing or planned DOE facilities as possible. This approach, referred to as "anchoring," provides the reference point used to estimate the various cost components. New designs were generated only if no existing data were available.

C.3.2.1.4 *Cost Components (Work Breakdown Structure)*

The costs for each WM facility included the following four components (each estimated separately): (1) pre-operational activities, including the costs of studies, demonstrations, generic designs, permitting, and startup; (2) facility construction, including definitive design, equipment and building, and construction labor costs; (3) O&M costs; and (4) decontamination and decommissioning (D&D) costs. Usages were determined separately for resources used during the construction period (which includes pre-operations and

construction) and resources used during the period of operations (which includes O&M and D&D). Life-cycle costs do not include speculative factors such as potential impacts on the long-term value of land.

Resource usage was estimated for all treatment, storage, and disposal facilities configured at each site for each waste type under each alternative. Building unit costs for various functions were developed by generating detailed material quantities, labor hours, and related costs for construction, using rates applicable to INEL. These building functional unit costs were multiplied by the functional floor space required within each module. The functional cost subtotals were summed to give a total building cost for each module.

Equipment costs were estimated either by soliciting budgetary costs from suppliers, by using existing data, or by making engineering judgments. Costs for the other three components of the estimate (operating budget-funded activities [pre-operation], O&M, D&D) were obtained from actual costs of existing facilities and from engineering estimates. These cost components do not include various site costs for the supporting infrastructure and basic site services known as "chargebacks." The allocation rules for chargebacks are site-specific and provide a similar site effect for all alternatives. They do not affect the relative cost ranking of the alternatives, and are not included in the PEIS.

To provide a comprehensive analysis of the WM facility requirements for support, the facilities required to manage the waste (for example, administration and maintenance) were also provided as separate facility cost modules. This approach facilitated analysis of scenarios that involve existing facilities where none, some, or all of the administrative functions may have already been in place.

C.3.2.1.5 *Cost Estimates Development*

To assist in application of the WMFCI, the baseline cost/capacity relationships defined for each cost module were translated into parametric cost relationships. These relationships were defined by linear and log-linear equations that uniquely define the costs over a broad range of capacity requirements. Each facility module had specific cost equations that defined the pre-operations costs, facility construction costs, O&M costs, and D&D costs. The cost relationships allowed the WMFCI to be consistently applied over a wide range of estimating scenarios.

Both DOE and the commercial nuclear industry have facilities similar to some of the cost modules examined by the WMFCI. Several facilities (for example, incinerators, metal-melters, supercompactors, spent nuclear fuel storage, and engineered disposal) were surveyed to obtain functional and operational requirements, capacity limitations, capital and operating costs, and other information needed to provide a basis for the WMFCI data.

To the extent possible, major equipment costs in each cost module were taken from similar facilities that had been constructed or that were in the advanced design stage. Before using costs from existing facilities, the data were adjusted to account for capacity differences and escalation. These cost validation steps established a cost confidence level for the PLCC estimates of plus or minus 30%.

Facility construction costs were based on the current cost-per-square-foot rates for five typical building functional envelopes defined by use—low hazard, moderate hazard, alpha-treatment, storage, and disposal functions—planned and under construction at INEL.

Indirect costs and overhead burden rates used in the cost-estimating methodology were based on those historically encountered at INEL. They fall approximately in the middle of the range of cost factors found at several other DOE sites and were therefore considered to be representative for complexwide estimating purposes.

C.3.2.2 WM PEIS Cost-Estimating Methodology

C.3.2.2.1 *Description of Alternatives*

Cost estimates for each PEIS alternative were developed at the module level for each site within the DOE complex. For a given WM alternative, every site with waste of that type played a role in management of that waste and consequently incurred some cost. The roles of the various sites could have ranged from simply packaging and shipping their own wastes to treating and disposing their own wastes and wastes from other sites. The contribution each site made toward the cradle-to-grave management of a given waste type was defined in each alternative through designation of treatment, storage, and disposal locations for each site's waste. The alternatives generally covered the range of possible configurations from a centralized waste

management strategy to a decentralized scenario. Other parameters that were also varied within the alternatives analyzed for a particular waste type included the level of treatment performed and the final waste form produced. Therefore, for each alternative, a unique set of responsibilities was defined for each site; this established the activities that had to be performed at each site and provided the basis upon which the cost estimates were developed.

C.3.2.2.2 *Waste Loads Development*

Once the WM activities to be performed at each site were defined for a particular alternative, the quantity of waste to be processed or handled through each module was calculated. This step was accomplished using a set of "raw" data that accounted for all waste stored and generated at each site. The waste information included quantities of waste currently in storage and projections for future waste generation. Each classification of waste (LLW, LLMW, TRUW, and HW) was broken down into "treatability groups." The treatability groups, based on the characteristics of the waste, helped to define which treatment processes were necessary to meet regulatory requirements for that waste type. (The generic configurations of processing modules necessary to treat, store, and dispose each waste treatability group were discussed earlier.) The raw data were transposed into the waste loads for each facility by applying the constraints and assumptions integral to the configuration designated for each alternative. Once a time factor was incorporated (for example, a 10-year operating period), the waste load for each module became a waste processing rate. The processing rates (throughput capacities) for each module was used to determine facility size and was the key factors used in developing the cost estimates.

C.3.2.2.3 *Existing Facilities Assessment*

A survey of existing and planned-or-approved WM facilities at each site, and their capacities, was performed to provide the baseline for cost-estimating purposes. Where existing capacities were identified, the total required operating capacity was reduced by that amount so that only the minimum necessary new facility construction was costed. Since existing facilities and their capacities were taken into account, the cost estimates developed for each alternative could be considered to be representative of actual future capital investments necessary to provide the additional capabilities required for the WM operations outlined in each alternative.

In some alternatives, where a homogeneous waste stream was currently being treated in a dedicated facility and actual operating costs were known, these actual costs were used in the PEIS cost estimates (rather than using bottom-up cost estimates for generic facilities designed to treat the same waste).

C.3.2.2.4 *Parameters and Assumptions*

The PEIS alternatives generally assumed that a 10-year implementation period was necessary to construct and start up the new WM facilities required for each alternative, and that a 10-year operating period would be used to work off the projected waste inventories. For new facilities, the costs of decontamination and demolition were included; for disposal facilities, the costs of custodial care after closure throughout a 300-year period of institutional control were included, but were not substantial.

Costs under the No Action Alternative for each waste type were estimated using a unique set of assumptions. The No Action Alernatives (with some exceptions for storage and disposal) used existing facilities for 20 years. This assumption was made to quantify the amount of useful facility life remaining in currently existing facilities. The assumption allows the current facilities to be considered for the complete 20-year period of analysis. Where projected waste loads exceeded existing treatment facility capacities, waste was assumed to be stored.

The HW alternatives were assumed to use commercial treatment contractors for 20 years; possible regional on-site treatment and disposal costs were also evaluated.

Costs associated with treating quantities totaling less than 0.1 pounds per hour or disposing quantities totaling less than 0.1 cubic feet per hour were considered to be insignificant and costs were not developed. These volume totals equate to treating a drum or less of waste per year and disposing 60 drums (one semi-trailer load) or less of LLW or LLMW per year. In such instances, bench-top-type treatment, or shipment to another facility, would be likely to occur.

The receiving and inspection module was used only for wastes received from another site for regionalized or centralized treatment. It was assumed that wastes generated on site would be characterized to the extent that inspection would not be required and that the waste could be transported directly to the treatment facility. Representative sampling of onsite waste characterization was assumed to be performed as necessary

through a variety of modules: certification and shipping (found at all sites), administration—with laboratory—(found at all treating, storing, and disposing sites), and waste characterization (found at all TRUW sites).

The "open, dump, and sort" module was used only for waste volumes currently in storage. It was assumed that these containerized wastes are heterogeneous and would need to be sorted before treatment. It was further assumed that wastes presently being generated or to be generated in the future would be segregated by treatment need and would not require sorting.

Except for TRUW, it was assumed that treated wastes would be accumulated in small batches (railcar or truckload quantities) and would be shipped directly for disposal, eliminating the need for storage. For TRUW, it was assumed that shipment could not be made directly to WIPP; therefore, costs were estimated for one year of storage before transportation to WIPP.

C.3.2.2.5 *Application of the Waste Management Facility Cost Information Methodology*

Curves for cost-versus-capacity and FTEs-versus-capacity were developed for each module through a bottom-up estimating method. These curves were developed over a finite range of capacities (referred to as the "standard capacity range") that, at the time the range was selected, would fit the anticipated cost-estimating needs. The standard capacity range selected was specific to each module. Cost versus capacity curves were developed for equipment (including installation), building requirements, operating labor, and operating materials. From these curves all other costs were determined through application of various cost factors. Combining all derived costs produced the life-cycle costs for each module. Costs for all modules were based on a 48-week year, three shifts per day, 5 days per week, and 70% availability, for a total operating period of 4,032 hours per year. The 4,032-hour year is a "rating" of achievable production capacity possible in a full 52-week workyear.

Curves for cost versus capacity were developed for numerous modules handling contact-handled (CH) LLMW, CH alpha-LLMW, RH LLMW, CH LLW, CH alpha-LLW, CH TRUW, RH TRUW, and HW. FTEs-versus-capacity curves were determined by applying a factor to the costs for an appropriate category.

With the release of updated waste data, the need for costs at capacities outside the standard capacity range of developed data became necessary. The following methodology was used to estimate the costs when the capacities fell outside the standard range for any particular module.

C.3.2.2.5.1 Costs Determination for Treatment Outside Standard Capacity Range

To estimate the costs for a treatment module at a throughput capacity falling below the standard range, the following extrapolation method was used. An "economy of scale" function was assumed to exist beyond the upper and lower bounds of the capacity-to-cost curve (developed as discussed above). The upper and lower bounds were the waste processing throughput capacities of the largest and smallest standard commercially available processing equipment for the particular module being adjusted. The basic formula is shown below:

[Cost for higher/lower capacity] = [Cost for high/low bounding point] × [(waste throughput capacity of higher/lower requirement)/(waste throughput capacity of high/low bounding point)] $^{0.7}$

The ratio of required throughput capacity to the throughput capacity of the high or low bounding point of the capacity-to-cost curve was raised to the 0.7 power. The use of the 0.7 power scaling factor was based on estimating methods presented by Peters and Timmerhaus (1968) and Remer and Chai (1990). The resulting value was used to adjust the cost of the equipment, building requirements, operating labor, and operating materials. These adjusted costs were then used to estimate the costs associated for the lower-than-standard capacity (to eliminate unrealistically small modules). A module was never scaled down to below 10% of the smallest capacity in the standard range. Similar judgment would have been used when scaling to modules several times larger than the upper bounding capacity; however, waste loads never became that large, so this approach was not tested.

For the incinerator module and the small generator front-end support module, costs were developed for a module of "minimum" size designation. This represented the smallest module size that could be constructed with off-the-shelf equipment. A slightly different approach was used to estimate costs. For capacities falling between the minimum capacity and the lowest capacity in the standard capacity range, the costs were determined by the method described above. For capacities falling at or below the minimum, the "minimum module" capital cost was used and operating costs were scaled down from the minimum capacity using the

0.7 power factor method. To eliminate an unrealistically small module for very small capacity requirements, the number of shifts was limited to 0.1 shift per workday.

For seven other non-alpha modules (aqueous waste treatment, wet-air oxidation, thermal desorption, deactivation, lead recovery, mercury separation, and polymer stabilization), the minimum module was the same as the lowest capacity in the standard range. Costs for these seven modules were treated in a parallel manner as stated for incineration (above). For capacity below the range associated with these seven modules, capital costs from the minimum module were used and the operating costs were scaled down from the minimum capacity using the 0.7 power factor method.

To determine the costs of an AGDSP or an SLDSP at a capacity falling below the standard range (18 to 126 cubic feet per hour), the following extrapolation method was used. For disposal capacities within the standard capacity range (1.44 to 5.9 cubic feet per hour) for the SIDSP, costs for silo disposal were used. For disposal capacities falling between the standard ranges of the SIDSP and the AGDSP or SLDSP (5.9 to 18 cubic feet per hour), the ratio of the actual capacity to the lowest capacity of the AGDSP or SLDSP standard capacity range was raised to the 0.7 power. The resulting factor was used to adjust the cost of the equipment, building requirements, operating labor, and operating materials. These adjusted costs were then used to estimate the associated costs. For disposal capacities falling below the standard capacity range of the SIDSP, costs were determined by scaling down with a factor developed by taking the ratio of the actual capacity and the smallest capacity in the standard range for the SIDSP raised to the 0.7 power.

C.3.2.2.5.2 Portable Module Costs

Small generator sites typically generate very small quantities of certain wastes. To treat these small quantities, installation of permanent treatment facilities would not always be cost effective. To handle these small quantities, portable treatment modules were identified as an economical alternative. Portable modules were used for certification and shipping, decontamination, polymerization (which is capable of performing grout stabilization for very small volumes), thermal desorption, and wet oxidation (which could substitute for incineration for very small volumes).

Costs for portable treatment modules were developed based on processing 2.5 cubic meters of waste per treatment campaign. Waste to be processed was assumed to have an incoming density of 40 pounds per

cubic foot for all modules, except aqueous waste, which has a density of 62.4 pounds per cubic foot. Each treatment campaign was assumed to require 2 weeks, including setup, processing, and shutdown. Counting travel time and equipment maintenance time, the number of campaigns was limited to 12 per year. (If waste quantities were sufficiently high to exceed 12 campaigns per year, permanently installed modules were estimated.) The portable equipment was assumed to have a useful life of 5 years, or 60 campaigns. A host facility (warehouse, garage, or similar structure) with suitable utility support was assumed to be required.

Costs associated with portable modules were developed on a campaign basis. Each portable module has its unique campaign cost, computed to include all programmatic life-cycle cost components.

C.3.2.2.5.3 Supplemental Cost-Estimating Methods

For most WM alternatives, costs, manpower, and resource use data were computed using the above-described methodology. The computations were made by selecting the same data results from cases estimated using the WMFCI methods in LLW Cases 5, 7, 12, and 14 for cost/manpower and in Cases 1, 2, 4, 5, 7, 12, 14, and 14a for resource data; in HW Case 1 for cost/manpower and Cases 1 and 2 for resource data; in TRUW Cases 1, 10, and 11 for resource data; and in LLMW Cases 1, 7, 10, and 17 for resource data. For certain data points, exact matches did not exist; in such instances, data were scaled linearly, using waste processing throughput proportions, from the nearest data point computed using the WMFCI method. These computations are summarized in *Data Collection on Existing and Planned/ Approved Waste Management Facilities in Support of the EM PEIS* (INEL, 1994). Resource use data estimates were discussed in Section C.3.1.

Where modifications to the originally computed data were required because of changes in costing assumptions, a similar "exact selection, or scaling from closest data point" method was used. These computations have been summarized (INEL, 1996).

In the case of HLW, cost and manpower estimates for canister storage and transportation were abstracted from the many cost studies performed for vitrification of HLW at the West Valley Demonstration Project (WVDP), Savannah River Site (SRS), Hanford, and INEL. A summary of these findings is found at Section C.3.2.2.8.

C.3.2.2.6 *Transportation Cost Estimates*

Transportation costs were calculated for each alternative using mileage between sites (either by highway or rail) and mass quantities requiring shipment. Transportation costs were included for waste shipments between generator sites and treatment sites, between generator sites and disposal sites, and between treatment sites and disposal sites. Costs were compiled for each alternative for both truck and rail transportation. Transportation costs for most waste types were computed using linear regression formulas, where a fixed cost per trip (depending upon waste type) was multiplied by the number of shipments and added to a variable cost-per-loaded-mile multiplied by the total shipping mileage. The fixed and variable costs per waste type and the background of the transportation cost-estimate development are provided (INEL, 1995e). The cost-estimating process for the transportation of HLW is found at Section C.3.2.2.9.

C.3.2.2.7 *Quality Assurance*

The PEIS cost estimates were compiled for each alternative, and the detailed estimating backup information is documented in data packages retained in the PEIS engineering files. Each cost data package was thoroughly reviewed before publication of any cost results. The quality reviews verified that the estimating methodology was correctly and consistently applied, that the assumptions and alternative descriptions were followed, and that the results provided reasonable PLCC that can be used to compare the relative costs of the various alternatives.

C.3.2.2.8 *Cost-Estimating Procedures for High-Level Waste Canister Storage and Transportation*

The generic cost methodology used was modified to reflect the specific assumptions for HLW. These modifications are discussed below.

C.3.2.2.8.1 Methodology and Assumptions

The life-cycle costs for facilities used for treatment, storage, and disposal are incurred from the beginning of the period of analysis, lasting for 20 years. The decontamination and decommissioning costs for new treatment and storage facilities, and custodial costs of disposal facilities, are also included. The total life-cycle costs include all costs associated with waste handling following its generation, current storage and treatment, transportation, future disposal and monitoring. The WM PEIS does not provide cost analysis of the current storage of HLW, pretreatment and treatment of HLW (resulting in canisters of vitrified waste), or environmental impacts of HLW disposal. The WM PEIS does provide cost analysis of the storage of canisters and the transportation to storage sites and a candidate geologic repository. Because of the possibility of a prolonged delay of HLW disposal, two sets of timing assumptions for acceptance of HLW at the candidate repository were analyzed.

Projecting the cost of the HLW alternatives involved developing estimates of the individual cost components. The cost was divided into two components—capital investment and annual operating charges. The capital cost of a facility was assumed to include process equipment, construction materials (for example, steel and concrete), and labor, as well as indirect costs such as those for design, contingencies, and environmental compliance. The annual O&M costs were expenses estimated for O&M staff, fixed and variable supplies, annual operating fees, administration, and general expenses. These two cost components were estimated by reviewing and abstracting available data on the costs of storage and transportation of HLW (ANL, 1996b).

C.3.2.2.8.2 Canister Storage

Vitrified HLW from Hanford, SRS, WVDP and INEL would be placed in on-site storage facilities awaiting transport to the candidate geologic repository. The WM PEIS alternatives for HLW management include: (1) No Action—Continued storage (assumed for 30 years), (2) Decentralized—All sites provide storage for canisters until the candidate geologic repository begins accepting DOE HLW in 2015, with shipments beginning in 2016; (3) Regionalized 1—WVDP ships its canisters to SRS for storage until transportation to the candidate repository starting in 2016; (4) Regionalized 2—WVDP ships its canisters to Hanford for storage until transportation to the candidate repository begins in 2016; and (5) Centralized—WVDP, SRS, and INEL ship their canisters to Hanford for storage until transportation to the candidate repository begins

in 2016. For the alternatives, the assumption was made that the approval of the candidate repository will occur in a timely manner so that the amount of storage facilities to be constructed could be kept to the minimum required.

The second set of timing assumptions is configured identically to the No Action, Decentralized, Regionalized 1, Regionalized 2, and Centralized Alternatives, except that acceptance of DOE HLW at the candidate repository is deferred past 2015, requiring the construction of storage facilities at each site capable of holding the full amount of canisters to be stored at that site. These alternatives are costed assuming that the approval of the candidate repository is made in time to begin transportation in 2016 but after each site has completed construction of storage facilities for all canisters produced at that site. Further deferrals of the decision will increase the total cost of storage. Depending upon the alternative, the costs for storage operations will increase by an additional $8 million for every year past 2015 that acceptance of HLW canisters at the candidate geologic repository is delayed.

The storage technology selected for costing is the modular dry vault storage (MDVS) concept. It is assumed that the interim canister storage facility at Hanford and at SRS for the vitrified HLW would hold canisters in vertically sealed cavities within a concrete structure forming the storage vault. Each canister storage vault (CISV) will be an air-cooled dry storage vault for vitrified HLW. A thermosyphon ventilation system would be used to remove heat generated by the stored vitrified HLW. Activities at a given CISV include receipt and unloading of transportation cask containing canister(s) of vitrified waste, inspection of the canister, and storage of the waste until transfer to a permanent geologic repository. The CISV consists of rows of tubes or vaults laced below grade into which the canisters are lowered. Concrete plugs provide a cover for the tubes. The canisters are to be stored in sealed sleeves so that the cooling air would not directly come into contact with the potentially contaminated surfaces of the HLW canisters. Although the design for storage of canisters at INEL has not been decided, the PEIS assumed the storage technology to be the same as that for Hanford and SRS. Because the storage facility has been constructed at WVDP, these costs are not included in the PEIS analysis.

The rationale for costing the construction and operations of these facilities is provided (ANL, 1996b). The cost experience for monitored retrievable storage facilities was modified to the above concept. The below formula was developed to estimate capital costs:

$$[\text{Capital Cost (\$ million)}]_{MVDS} = 0.71\ [\text{Capacity (HLW Canister)}]^{0.53}$$

Annual O&M costs include the routine handling, storage, and retrieval, with the predominance of costs pertaining to the operation of facilities. The operating lifetime of the various storage facilities varies depending upon the transportation instruction for each Alternative. The correlation of the annual operating costs for the storage period as a function of capacity is:

$$[\text{Annual O\&M Cost (\$1,000/yr)}]_{\text{Storage}} =$$
$$38.6 + 0.27 \times [\text{Capacity (HLW canisters being stored)}]$$

Loading/unloading operations were evaluated in the reference; the following formula was developed:

$$[\text{Annual O\&M Cost (\$1,000/yr)}]_{\text{Loading}} = 770 \times [\text{Throughput (HLW Canisters shipped/yr)}]^{0.52}$$

With respect to the shipping rate to be assumed for the various alternatives, the loading rate into storage is taken to equal the maximum annual vitrification rate (190 canisters per year for SRS, 790 canisters per year for Hanford (No Action is 320 canisters per year), 300 canisters per year for WVDP, and 327 canisters per year for INEL). The total time for unloading the HLW canisters before shipment to the candidate repository is assumed to be performed at a rate of 800 canisters per year. The loading/unloading duration is dependent upon the shipping rate.

The quantities and timings shown in Chapter 9 were applied to the formulas C-1, C-2, and C-3, and totaled for each alternative under both sets of timing assumptions. The computation summaries are provided (INEL, 1996).

C.3.2.2.9 *Transportation of Vitrified HLW Canisters*

The rationale for costing transportation of HLW canisters between sites is provided in ANL (1996b). Based on numerous reports, there is general agreement that transportation costs for HLW would be similar in cost for spent nuclear fuel. The life-cycle cost for HLW transportation can, in general, be calculated by summing the following cost categories: shipping cost; security cost; cask, capital and decommissioning cost; cask maintenance cost; inspection cost; demurrage cost; handling cost (loading and unloading); and transportation support system costs.

The following assumptions were made for the HLW transportation cost analysis:

- The costs associated with the inspection cost category are included in the annual operating charges for the various HLW storage facilities.
- Demurrage (the charge for the detention of a freight car or truck by the shipper or receiver beyond the time allowed for loading, unloading, or shipping) is assumed to be negligible in comparison with other cost components.
- The handling cost for loading and unloading at the HLW storage facility has already been considered in the storage cost; the handling cost at the candidate repository is assumed to be out-of-scope for this PEIS.
- Transportation support system cost include the costs to maintain the railcars and trailers which are assumed to be negligible (average annual O&M cost for a truck trailer is approximately $14,000; for a rail car, $5,000).

Table C.3–2 presents the formulas used to compute truck and rail transportation costs.

C.4 Phase III: Environmental Impacts Evaluation

This section describes the scientific approach and analytical methods used to evaluate the impacts of the WM alternatives on air quality, water resources, ecological resources, the local and National economies and social environments, environmental justice issues, land use, infrastructure, and cultural resources.

The general impacts methods were applied as appropriate to analyze the effects of management alternatives for each of the five waste types. Construction and operation of treatment, storage, and disposal facilities and intersite transportation of wastes were the principal activities analyzed for impacts, as applicable (Table C.4–1) under each of the waste-type alternatives.

The engineering analysis Phase II output data served as the input data for the environmental impacts assessments. These engineering outputs included estimates of the costs, labor, and resources required to build and operate the WM facilities and estimated facility discharges of pollutants to air and water.

Air quality impacts were analyzed by comparing estimated pollutant increases to applicable standards for the Air Quality Control Region (AQCR) at each site. The analysis addressed criteria pollutants, airborne

Table C.3-2. Assumed Relationship for the Four Transportation Cost Components

Cost Variable	Relationship Assumed in This Study	
	Rail-Based	**Truck-Based**
SPEED (mph)	DIS/(0.04204 × DIS + 4)[a]	35 (i.e., a constant value)[b]
Annual Cask Requirement, ACR	$\sum$ {[(2 × DIS)/SPEED$_{rail}$]/24 + 2 × (5 days)}[c]	$\sum$ {[(2 × DIS/SPEED$_{truck}$]/24 + 2 × (3 days)}[c]
Shipping Cost, less than 1,000 miles (1985 dollars)	$\sum$ ([2.32 + 0.0067 × DIS] × 2,000) + ([2.15 + 0.0063 × DIS] × 1,800) × [No. of Canisters]/5[c,d]	$\sum$ ([1.493 + 0.0033 × DIS] × 500) + ([0.428 + 0.0034 × DIS] × 475) × [No. of Canisters][c]
Shipping Cost, greater than 1,000 miles (1985 dollars)	$\sum$ ([5.07 + 0.004 × DIS] × 2,000) + ([4.72 + 0.0037 × DIS] × 1,800) x [No. of Canisters]/5[c,d]	$\sum$ ([-0.16 + 0.0049 × DIS]× 500) + ([-0.19 + 0.004 × DIS]× 475) × [No. of Canisters][c]
Security Cost (1985 dollars)	$\sum$ {291.65 × [DIS$^{-0.5987}$]× DIS} × [No. Of Canisters]/5	$\sum$ {7.93 × [DIS$^{-0.1855}$]× DIS} × [No. of Canisters]
Cask Capital Cost (1985 dollars)[e]	$\sum$ (ACR/300) × [No. of Canisters] × (2.5 × 10^5)	$\sum$ (ACR/300) × [No. of Canisters] × (1.5 × 10^5)
Cask Maintenance Cost (1985 dollars)[f]	$\sum$ (ACR/300) × [No. of Canisters] × (2.5 × 10^4)	$\sum$ (ACR/300) × [No. of Canisters] × (1.5 × 10^4)

[a] DIS = distance traveled (one-way miles); is a function of WM PEIS alternative.
[b] Conservative value, based on DOE (1986); a value of 40 mph is cited in DOE (1991).
[c] The summations are to be performed over all shipping routes.
[d] Assumes five HLW canisters per rail shipping cask, one HLW canister per truck shipping cask (DOE, 1986).
[e] Assumes a capital cost of $2.5 million for rail cask, $1.5 million for truck cask (both in 1985 dollars) (DOE, 1986).
[f] Assumes an annual maintenance cost of $125,000 for rail cask, $75,000 for truck cask (both in 1985 dollars) (DOE, 1986).

radionuclides, and other hazardous and toxic air pollutants from construction and operation of WM facilities at each DOE site. Criteria pollutant increases from mobile (transportation) and stationary sources were evaluated, as applicable.

Water resources impacts were analyzed by evaluating the effects on natural water sources of the use or discharge of large volumes of water during construction or operation of WM facilities at each site. Water quality impacts were evaluated for hypothetical releases of waste, that could leach into groundwater the releases were assumed to come from deteriorating packages or containers in disposal facilities.

Table C.4-1. WM Actions Analyzed for Environmental Impacts

WM Action	Waste Type				
	LLMW	LLW	TRUW	HLW	HW
Treatment Facility Construction and Operation	✓	✓	✓		✓
Storage Facility Construction and Operation	✓[a]		✓	✓	
Disposal Facility Construction and Operation/(& Postclosure Effects)	✓	✓			
Transportation of Wastes Between Sites	✓	✓	✓	✓	✓
Waste Transport to Repository or Commercial Treatment/Disposal			✓	✓	✓

[a] For No Action Alternative only.

Ecological impacts were evaluated in terms of the potential for loss of habitat from site clearing for WM facility construction, indirect facility construction and operation effects on sensitive habitats, exposure of terrestrial species to airborne contaminants released from treatment facilities, and a scenario-based assessment of the consequences of releases of wastes to aquatic habitats in transportation accidents.

Economic impacts were analyzed by estimating employment and income increases in the regional economies supporting the DOE sites that might be caused by the infusion of funds to build and operate WM facilities. Impacts on the National economy were also assessed using the sum of all expenditures at all sites and for waste transportation under each waste-type alternative.

Population impacts were evaluated in terms of changes caused by the in-migration of workers in response to increased labor requirements for construction and operation of facilities.

An analysis of environmental justice considerations—disproportionate effects on minorities or low-income populations—discusses and displays the minority and poverty status of the populations at each WM site to highlight sites where those populations might be disproportionately affected by WM activities.

Land use impacts were evaluated by estimating the likelihood that building WM facilities at the sites under a WM alternative would require a commitment of land that might substantively alter the use of land at the site or that might require DOE to acquire additional land to implement the alternative. Conflicts with site development plans and current adjacent land uses were also considered.

Infrastructure impacts were evaluated by estimating the effects of building and operating WM facilities on site water supply, waste water treatment facilities, electrical power supply, and transportation infrastructure. Community infrastructure impacts were evaluated in terms of the estimated level of increased demand on community infrastructure caused by the influx of new labor and their families to support the WM projects.

The potential for cultural resources effects was considered comparatively in terms of the extent of construction site disturbance at each site under each alternative as an indicator of the requirement for cultural resources surveys that would be conducted at the site or project level. Impacts on cultural resources were not evaluated directly because the WM facility locations on each site are not yet proposed.

Environmental impacts considered in the PEIS, but not evaluated in detail, included effects on geology and soils, the noise environment, and visual resources. Those impacts are discussed in Chapter 5 of the PEIS.

All chemical and radiological discharges and direct radiation effects were estimated using computer models that simulate the fate and transport of contaminants in the environment. The computer models are described in the sections on air quality, water resources, and ecological resources. The models are further described in the facility risk appendixes (Appendices D and F) and the transportation risk appendix (Appendix E).

C.4.1 Human Health Impacts

C.4.1.1 Human Health Risk Assessment for Waste Treatment, Storage, and Disposal

Human health risk assessments were conducted for the construction and operation of treatment and storage facilities, for hypothetical individuals exposed downgradient of disposal facilities, for transportation of wastes, for accidents involving facilities at the sites, and for transportation accidents. Details of the human health risk assessment that estimated risks at the facilities resulting from routine construction and operation activities and from facility accidents are given in Appendix D. Details of the routine transportation and transportation accident risk assessments are given in Appendix E. Further details of the facility accident risks are given in Appendix F.

C.4.1.2 Population Risk Vulnerability Evaluation for LLMW and LLW Disposal

The objective of the population risk vulnerability analysis was to develop a basis for comparison of LLMW and LLW disposal alternatives using measures that characterize their relative potential to cause risks to offsite populations from groundwater contamination.

C.4.1.2.1 *Introduction*

Although maximally exposed individual (MEI) and population (or collective) risk estimations are both routinely used to characterize the potential health consequences of Federal agency actions, certain considerations led DOE to conclude that an alternative to collective risk estimation was needed for comparison of LLMW or LLW disposal alternatives in the WM PEIS.

First, other DOE efforts to address disposal risk do not generally estimate population risk. DOE has been addressing the issue of protecting the public from the effects of exposures to radioactive and mixed waste constituents released from disposal facilities. Ongoing Department efforts include performance assessments conducted for LLW disposal facilities in compliance with the requirements of DOE Order 5820.2A (DOE, 1988) and performance evaluations conducted for candidate LLMW disposal sites by the FFCAct Disposal Workgroup. Although these efforts currently address risks to single individuals at specified compliance points, they do not attempt to predict collective risks to current or future populations. A brief description of these efforts is provided in Section C.4.1.2.5.

Second, DOE determined that estimation of offsite population risk from exposure to disposal facility contaminants in the WM PEIS would require too many speculative assumptions and would not provide a credible basis for comparison of LLMW or LLW disposal alternatives. The concentrations of contaminants in the groundwater and the number of people potentially exposed will be determined in large part by the locations of the disposal units and the receptor wells. Estimation of the number of adverse health effects in current offsite populations would require information about the exact locations of the disposal facilities on the sites. Since the WM PEIS does not attempt to make such siting decisions, offsite population doses (e.g., person-rem) and risks (e.g., number of latent cancer fatalities) from disposal were not estimated. Analysis of future offsite population risks requires similar siting information and involves additional

uncertainty with respect to the sizes of future populations. Therefore, the WM PEIS could not credibly estimate adverse health impacts from disposal for future offsite populations.

Therefore, an alternative analysis methodology was needed for the WM PEIS to characterize the LLMW and LLW disposal alternatives that would utilize relevant information about the sites but that would not require quantitative estimates of collective dose and risk. This section describes the statistical methodology and data used to characterize the population risk vulnerability of the proposed disposal sites and to compare the population risk vulnerability of the disposal alternatives. The results of the analysis are presented in Chapters 6 and 7 of WM PEIS Volume I.

C.4.1.2.2 *Analytical Methods*

The two-part methodology consisted of (1) a factor analysis to identify the principal axes of variability of the site environmental data and relate those factors to population risk vulnerability and (2) a cluster analysis to identify distinct groups of sites on those principal axes.

C.4.1.2.2.1 Factor Analysis

Factor analysis is a statistical technique that can be used to identify a relatively small number of factors to represent relationships among a set of many interrelated variables (Norusis/SPSS Inc., 1993). The factors are derived to explain the observed correlations among the interrelated variables. The more highly correlated the original set of observations (cases) on the variables, the fewer factors are required to describe the relationships—that is, the more of the total variability in the data set can be represented by the first few derived factors. If the variables are completely uncorrelated, factor analysis will not provide a more compact explanatory solution than the original variables. A good factor solution is also interpretable. The factors can be interpreted as revealing underlying attributes of the variable set that can be readily described in broad terms.

Norusis/SPSS Inc. (1993) describe a four-step procedure for factor analysis:

1. Correlation matrix computation and factor model assessment
2. Factor extraction

3. Factor rotation
4. Factor score computation

In step 1, the interrelatedness of the variables is determined by examination of the simple Pearson correlation coefficients and some simple statistical tests of the correlation matrix to determine if a factor analysis is an appropriate technique to apply to the data set. In step 2, factors are extracted, usually initially by using principal components extraction, in which linear combinations of the variables are derived. These principal component vectors account in sequence for decreasing portions of the data variability and are independent of one another (orthogonal). The principal components may then be interpreted by the analyst as identifying a general underlying measure of the variables. In step 3, the initial factor solution is rotated to produce factors that are easier to interpret. In step 4, the factor scores for each case are computed by multiplying the original variable set by the principal components or rotated factors. These factor scores can be plotted to show how the different cases relate to each other in factor-space.

C.4.1.2.2.2 Cluster Analysis

Cluster analysis is a statistical technique used to identify relatively homogeneous subgroups or clusters from data on members of a larger population. Members of these subgroups can then be considered to share common characteristics and to be relatively distinct from other subgroups in terms of the important measured variables used to determine the clusters (Norusis/SPSS, Inc., 1993). Cluster analysis establishes groupings based on distance/nearness calculations for a set of specified variables. In the most commonly applied calculation method, clusters are derived by using squared Euclidean distances.

C.4.1.2.3 *Analysis Methods Applied to Population Risk Vulnerability of WM Disposal Sites*

C.4.1.2.3.1 Selection and Transformation of Explanatory Variables

The variables selected for use in the factor and cluster analyses of the 16 candidate disposal sites were six site characteristics that were considered likely to cause or be associated with future levels of offsite population risk from radioactive or mixed waste disposal: annual rainfall, annual groundwater recharge,

aquifer depth, travel time of water (from the time it infiltrates the ground surface to the time it reaches the aquifer and appears in a downgradient well), current human populations within 50 miles of the site, and site acreage (Table C.4–2). The first three variables, which characterize the surface and groundwater hydrology of the sites, are measures known to determine the speed, duration, and extent of dispersal of contaminants from disposal facilities and the level of resulting downgradient contaminant concentrations in groundwater. The estimates of travel time are based on the physical properties of the soils, the aquifer depth, and the groundwater velocity at each site. Current census population levels are considered the most appropriate measure of the potential size of the population at risk in the near term, at least on a relative basis from site to site. Site acreage provides an indirect measure of two associated characteristics — the size of the potential populations at risk and the likelihood that contaminants in downgradient groundwater would appear in a publicly accessible wellwater source. Site size is related to population size because the larger sites exclude population growth on extensive areas. Site size is related to groundwater contamination and exposure because of the relationship between the proximity of offsite population centers to locations on the sites where disposal facilities would be constructed. Data on annual rainfall, aquifer depth, current human populations within 50 miles of the site, and site acreage were taken from ORNL (1995c). Estimates of time of travel were made using environmental setting data on unsaturated and saturated soil zones for the 16 disposal sites provided in ORNL (1995c). Data on annual groundwater recharge was taken from SNL (1996). These site characteristics are generally strongly correlated with each other — for example, the smaller sites tend to be situated in regions of denser population with higher rainfall. Therefore, it was expected that the six variable measures could be represented by a limited number of principal factors that are composite measures of the important variations in the site characteristics.

Examination of the variable distributions (see, for example, Figures C.4–1 and C.4–2) showed that many were not normally distributed, so log transformations were performed to create a more linearized data set (Table C.4–3). These transformations ensure a more appropriate application of the statistical general linear model and, among other benefits, help minimize the tendency for larger measures to be unduly weighted in the factor solutions.

Table C.4–2. Environmental and Population Data Used to Group Disposal Sites in Terms of Population Risk Vulnerability

Site	Population Within 50 mi	Acreage	Annual Rainfall (cm)	Aquifer Depth (ft)	Annual Aquifer Recharge (ft/yr)	Time of Travel of Water to Downgradient Well (years)
ANL-E	7,939,785	1,025	80	90	0.33	246
BNL	5,738,554	5,263	107	200	0.50	59
FEMP	2,764,589	1,050	104	59	0.50	18
Hanford	377,645	370,656	16	236	0.16	191
INEL	153,061	572,160	23	600	0.23	298
LLNL	6,324,234	6,900	36	98	0.08	70
LANL	159,152	28,000	47	749	0.05	411
NTS	14,266	864,000	19	787	<0.001	1,352
ORR	895,379	34,560	139	26	0.60	11
PGDP	500,502	3,425	120	49	0.43	17
Pantex	265,185	16,000	51	320	0.02	175
PORTS	639,062	4,032	101	24	0.39	24
RFETS	2,171,877	6,550	38	18	0.16	25
SNL	610,714	2,791	20	94	0.06	132
SRS	620,618	192,700	122	110	1.30	23
WVDP	1,698,391	220	104	10	0.23	226

Notes: ANL-E = Argonne National Laboratory-East; BNL = Brookhaven National Laboratory; FEMP = Fernald Environmental Management Project; Hanford = Hanford Site; INEL = Idaho National Engineering Laboratory; LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; NTS = Nevada Test Site; ORR = Oak Ridge Reservation; PGDP = Paducah Gaseous Diffusion Plant; Pantex = Pantex Plant; PORTS = Portsmouth Gaseous Diffusion Plant; RFETS = Rocky Flats Environmental Technology Site; SNL = Sandia National Laboratories; SRS = Savannah River Site; and WVDP = West Valley Demonstration Project.

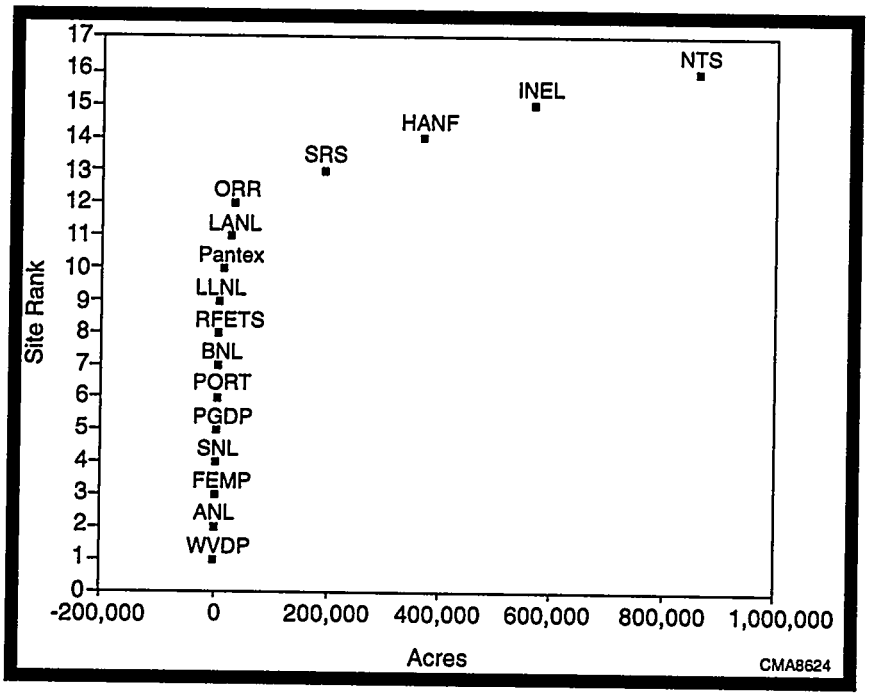


Figure C.4–1. Sites Plotted According to Increasing Acreage, Showing Nonlinearity in Data.

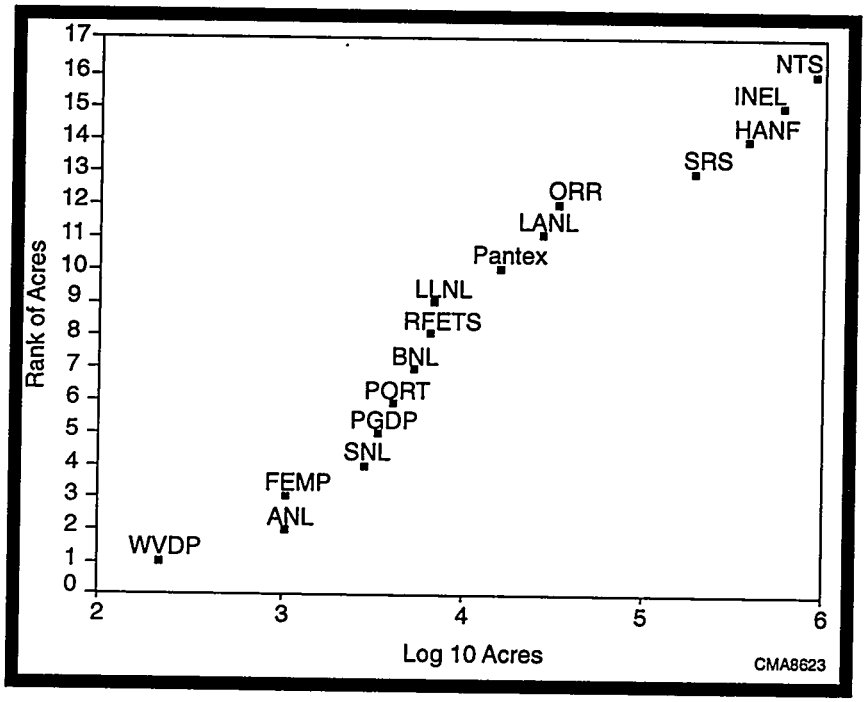


Figure C.4–2. Sites Plotted According to Increasing Site Acreage, Showing Applicability of Loglinear Transformation.

Table C.4–3. Transformed Environmental and Population Data Used to Categorize Disposal Sites in Terms of Population Risk Vulnerability

Site	log10 (Population in 50 mi)	log10 (Acreage)	log10 (Annual Rainfall [cm])	log10 (Aquifer Depth)	log10 (Recharge [m/yr])	log10 (Distance to Water)
ANL-E	6.90	3.01	1.90	1.95	-0.48	2.39
BNL	6.76	3.72	2.03	2.30	-0.30	1.77
FEMP	6.44	3.02	2.02	1.77	-0.30	1.25
Hanford	5.58	5.57	1.20	2.37	-0.80	2.28
INEL	5.18	5.76	1.36	2.78	-0.63	2.47
LLNL	6.80	3.84	1.56	1.99	-1.10	1.85
LANL	5.20	4.45	1.67	2.87	-1.30	2.68
NTS	4.15	5.94	1.28	2.90	-3.00	3.13
ORR	5.95	4.54	2.14	1.41	-0.22	1.03
PGDP	5.70	3.53	2.08	1.69	-0.37	1.22
Pantex	5.42	4.20	1.71	2.65	-1.69	2.24
PORTS	5.81	3.61	2.00	1.38	-0.41	1.37
RFETS	6.34	3.82	1.58	1.26	-0.80	1.40
SNL	5.79	3.45	1.30	1.97	-1.22	2.12
SRS	5.79	5.28	2.09	2.04	0.11	1.36
WVDP	6.23	2.34	2.02	1.00	-0.64	2.35

Notes: ANL-E = Argonne National Laboratory-East; BNL = Brookhaven National Laboratory; FEMP = Fernald Environmental Management Project; Hanford = Hanford Site; INEL = Idaho National Engineering Laboratory; LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; NTS = Nevada Test Site; ORR = Oak Ridge Reservation; PGDP = Paducah Gaseous Diffusion Plant; Pantex = Pantex Plant; PORTS = Portsmouth Gaseous Diffusion Plant: RFETS = Rocky Flats Environmental Technology Site; SNL = Sandia National Laboratories; SRS = Savannah River Site; and WVDP = West Valley Demonstration Project.

C.4.1.2.3.2 Factor Analysis of Environmental Variables

C.4.1.2.3.2.1 Correlation Matrix Computation and Appropriateness of the Factor Model

Simple correlations among the transformed environmental variables were computed (Table C.4–4). Measures of the appropriateness of the factor model were computed, including Bartlett's test of sphericity, the Kaiser-Meyer-Olkin (K-M-O) overall measure of sampling adequacy, and individual measures of sampling adequacy. Bartlett's test gave a value of 50.61 with a significance of 0.00001, indicating that it is highly unlikely that the variables are uncorrelated. The K-M-O value of 0.64851 indicates that correlations between pairs of variables can be adequately explained by the other variables. The substantial degree of correlation shown between variables and the results of the appropriateness tests indicated that factor analysis would be a fruitful technique for investigation of the data.

Table C.4–4. Correlation Matrix of Transformed Environmental Variables

	Site Acreage	Aquifer Depth	Population in 50 mi	Annual Rainfall	Groundwater Discharge	Time of Travel
Site acreage	1.00000					
Aquifer depth	.67119	1.00000				
Population in 50 mi	-.70651	-.57654	1.00000			
Annual rainfall	-.52114	-.54939	.47536	1.00000		
Groundwater recharge	-.35054	-.55470	.64883	.66101	1.00000	
Time of travel	.32030	.66135	-50204	-.65108	-.73246	1.00000

C.4.1.2.3.2.2 Factor Extraction

The first principal component derived in the analysis (Table C.4–5) accounts for approximately 64% of the variability (information content) in the site characteristics data. It is a vector that substantially measures all six variables—the absolute values of the loadings (vector elements that, by vector multiplication, transform the original data set into the components) exceed 0.5 for all variables. It can be interpreted as accounting for the fact that the smaller sites are generally the sites with higher populations and wetter hydrologic conditions. These conditions include higher rainfall, a generally shallow water table, and a relatively short groundwater time of travel. The second principal component accounts for an additional 15% of the data variability but is not as readily interpretable. (The sites are plotted according to their scores on the first two principal components in Figure C.4–3.) Therefore, factor rotation was performed to derive factors that could be more satisfactorily interpreted.

C.4.1.2.3.2.3 Factor Rotation

The factor rotation technique selected for the analysis, oblique rotation, produces more easily interpretable factors in this instance, although the factors are not independent. The first two oblique factors (Table C.4–5)

Table C.4–5. First Two Principal Components of Site Environmental Variables and Rotated Factors Derived From Oblique Rotation of the Principal Components

	Principal Components		Rotated Factors	
Site Environmental Variables	**First PC**	**Second PC**	**First RF**	**Second RF**
Acreage	-.73202	.63199	.20112	1.07112
Aquifer depth	-.83433	.15024	-.37317	-.57330
Population within 50 mi	.80974	-.30622	.19267	-.73860
Rainfall	.80146	.21037	.73326	-.14784
Groundwater recharge	.82579	.37202	.91960	.02403
Time to travel to downgradient well	-.80913	-.44507	-.98616	-.11504

can be interpreted as (1) a site hydrology factor that is positively loaded on rainfall and groundwater recharge and negatively loaded on time of travel of water to a downgradient well, and (2) a general site characteristics factor that might be described as the "small, shallow water table, high population" factor. The factors have a correlation of -.58603; sites that have higher scores on oblique factor 1 tend to have lower scores on oblique factor 2.

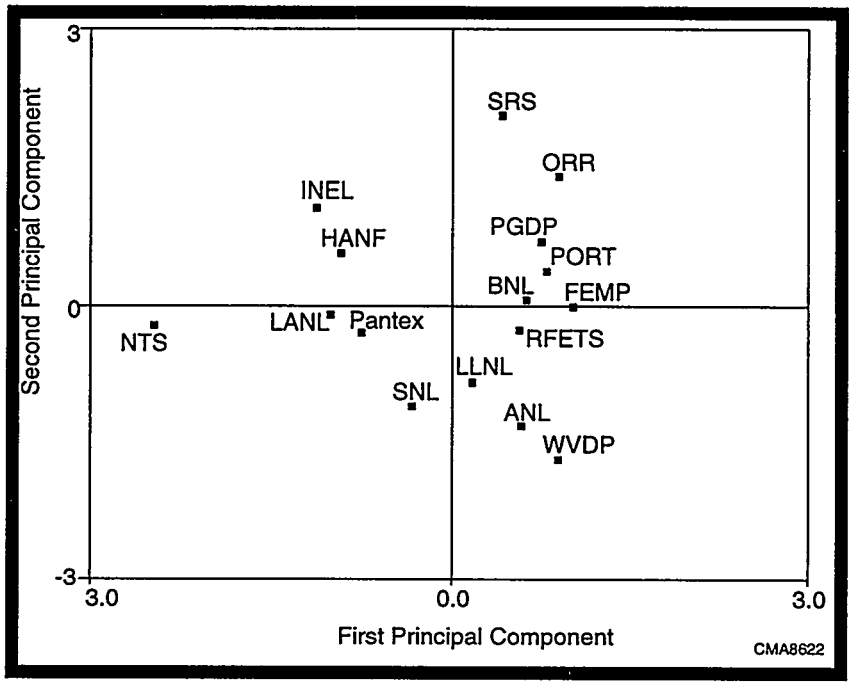


Figure C.4–3. Sites Plotted According to Their Scores on the First Two Principal Components of the Environmental Data.

C.4.1.2.3.2.4 Oblique Factor Scores

Sites are plotted according to their scores on the first two oblique factors in Figure C.4–4. To provide a more understandable presentation of the rotated factors, the site scores on the second oblique factor were reversed (multiplied by negative 1) before being plotted in the oblique factor diagram. Sites to the right in the diagram have higher scores on the first factor, indicating that they have groundwater hydrologic conditions that would tend to move contaminants more quickly downgradient from disposal units and possibly to drinking water wells that might be used by the public. Sites to the left in the diagram are those where site characteristics would tend to limit migration of contaminants and increase the time over which any movement might result in wellwater contamination. In terms of scores on the second factor, sites plotted in the upper portion of the diagram are those that are smaller in size with higher surrounding populations. Those plotted lower are the larger sites with lower surrounding populations. Land uses on and near the sites, the site size itself, and the size of the surrounding populations are more likely to change substantially during the time contaminants may be leaching from disposal units than are the physical characteristics of the site. Therefore, DOE considers the first factor scores more important than the second factor scores in characterizing the sites' relative potentials for offsite population risk.

C.4.1.2.3.3 Derivation of Population Risk Vulnerability Groups

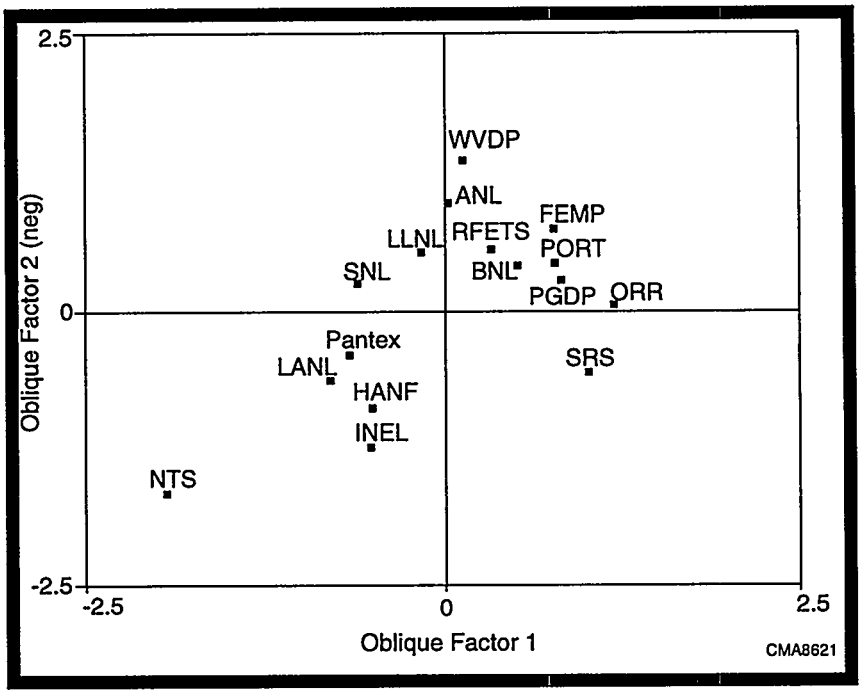


Figure C.4–4. Sites Plotted According to Their Scores on the First Two Oblique Factors of the Environmental Data.

The factor analysis provides a general indication of the relative population risk vulnerability of the 16 proposed disposal sites. The factor scores of the 16 sites show relationships among the sites in hydrologic and population characteristics that would be reasonable to conclude would be directly related to the levels of population dose and risk. DOE further identified distinct groups of sites representing similar levels of potential for population risk from waste disposal. The sites were grouped using a cluster analysis of the same six site characteristics.

In the cluster analysis, DOE used the site environmental data on the six variables to calculate measures of overall difference among the 16 sites. These difference measures were used to extract clusters of sites by combining sites with generally similar characteristics. The difference measures are greater between clusters than they are for sites within a cluster. By labeling the factor plots with the cluster membership of each site, distinct risk vulnerability groupings were identified. A dendrogram (Figure C.4–5) illustrates the combining of the sites into a decreasing number of clusters on the basis of the squared-Euclidean distance method applied to the standardized variables until all 16 sites are combined. A set of five clusters was derived for the population risk vulnerability analysis. Reading of the dendrogram from left to right as sites are successively linked, the last five clusters derived were used in the population risk vulnerability analysis. Two of the five clusters combine ANL, BNL, LLNL, RFETS, and SNL in Cluster 1 and combine FEMP, ORR, PGDP, PORTS, and SRS in Cluster 2. Hanford, INEL, LANL, and Pantex are linked as Cluster 3. NTS and WVDP are distinct enough to remain as separate Clusters 4 and 5. Sites are arrayed by cluster number in Figure C.4–6.

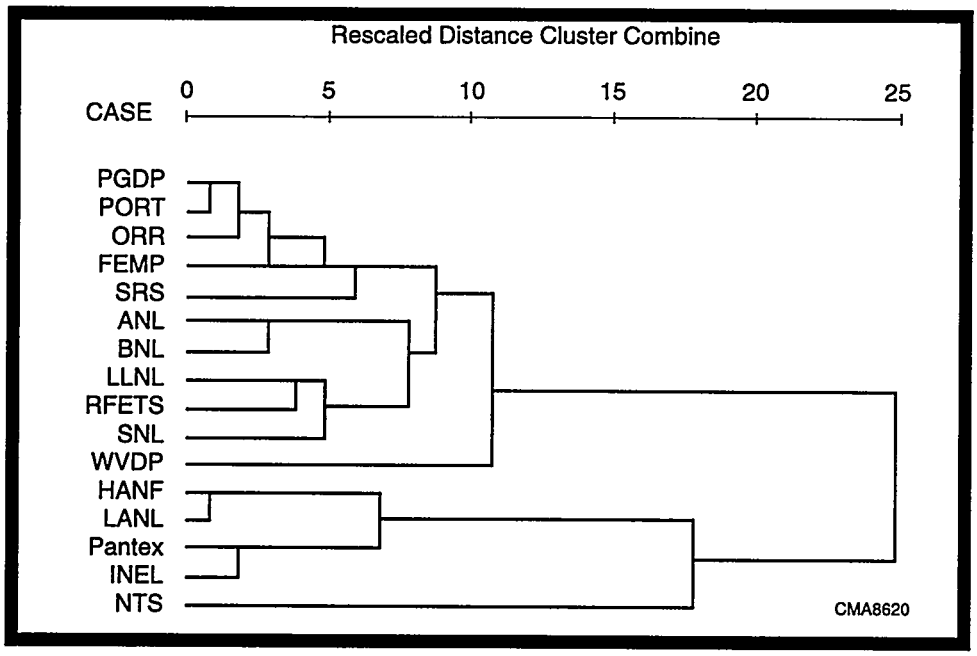


Figure C.4–5. Dendrogram Illustrating Derivation of Site Clusters From Environmental Data.

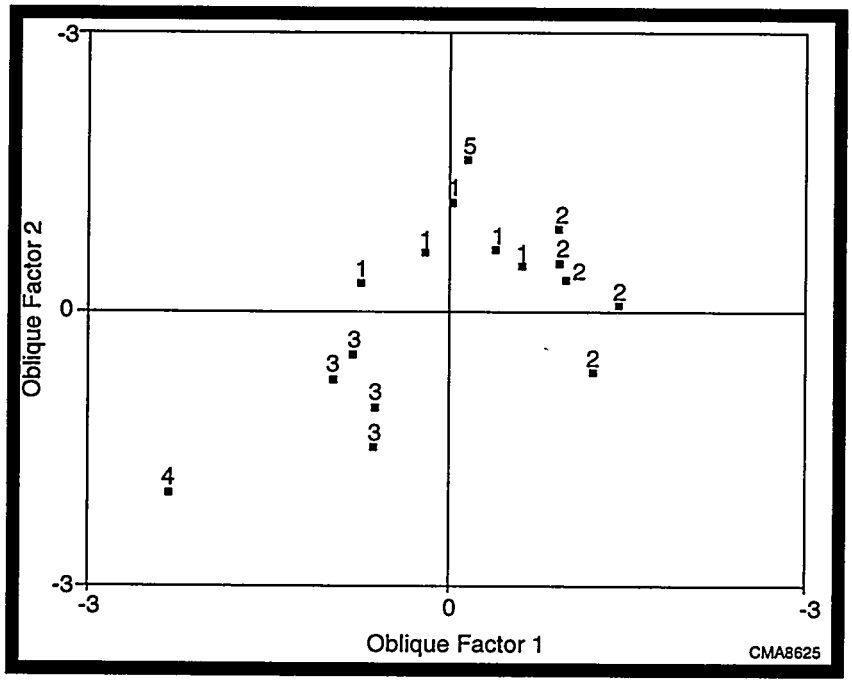


Figure C.4–6. Sites Arrayed by Cluster Number According to Their Scores on the First Two Oblique Factors of the Environmental Data.

The cluster analysis was used to identify three general site groups according to their expected relative population risk vulnerability. The single-site clusters (4 and 5) were combined with their nearest neighbor clusters. The resulting groups were renumbered to indicate higher (3), intermediate (2), and lower (1) relative population risk vulnerability. The groups are listed with the basis of their relative population risk vulnerability ratings in Table C.4–6.

C.4.1.2.4 *Comparison of LLMW and LLW Alternatives by Population Risk Vulnerability*

LLMW and LLW disposal alternatives were arrayed in terms of greater or lesser potential for population risk based on the population risk vulnerability designation of the sites proposed for disposal under each alternative and the waste volume, curie load, and number of disposal units required at those sites. LLMW

Table C.4–6. Interpretation of Site Clusters in Terms of Relative Potential for Offsite Population Risk From Disposal

Population Risk Vulnerability Group Number	Relative Offsite Population Risk Level	Original Cluster Number	Sites in Cluster	Scores on Oblique Factors	
				Hydrology	Site Size/Population
3	Higher	2	FEMP, ORR, PGDP, PORTS, SRS	High	Intermediate
2	Intermediate	5	WVDP	Intermediate	Highest
		1	ANL, BNL, LLNL, RFETS, SNL	Low to Intermediate	Intermediate to High
1	Lower	3	HANF, INEL, LANL, Pantex	Low	Low to Intermediate
		4	NTS	Lowest	Lowest

Notes: ANL = Argonne National Laboratory; BNL = Brookhaven National Laboratory; FEMP = Fernald Environmental Management Project; Hanford = Hanford Site; INEL = Idaho National Engineering Laboratory; LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; NTS = Nevada Test Site; ORR = Oak Ridge Reservation; PGDP = Paducah Gaseous Diffusion Plant; Pantex = Pantex Plant; PORTS = Portsmouth Gaseous Diffusion Plant; RFETS = Rocky Flats Environmental Technology Site; SNL = Sandia National Laboratories; SRS = Savannah River Site; and WVDP = West Valley Demonstration Project.

and LLW alternatives were then summarized in terms of the total waste volume, curie load, and number of disposal units required at all sites within each population risk group. Those alternatives with greater volume, curie load, and number of disposal units at group 3 sites could generally be considered to represent a relatively greater risk to populations than alternatives that concentrate disposed wastes at group 1 and 2 sites. From a population risk perspective, alternatives that concentrate disposed wastes at group 1 sites would represent the lowest risk.

C.4.1.2.5 *Disposal Analyses Conducted for DOE*

As a basis for analysis of radiological waste disposal, DOE issued Order 5820.2A (DOE, 1988), which requires DOE to dispose of all LLW and LLMW in a manner that ensures protection of the health and safety of the public.

DOE Order 5820.2A (DOE, 1988) contains policies, guidelines, and minimum requirements established by DOE for managing its radioactive waste, mixed waste, and contaminated facilities. Chapter III of this order is applicable to the management of LLW. The specific performance objectives set forth in this order state that DOE LLW that has been disposed of after issuance of the order shall be managed in a way that achieves the following goals:

- Protect public health and safety in accordance with standards in applicable environmental health orders and other DOE Orders.
- Ensure that external exposure to the waste and concentrations of radioactive material that might be released into surface water, groundwater, soil, plants, and animals results in an effective dose equivalent (EDE) that does not exceed 25 mrem/yr to any member of the public. The EDE is the sum of the products of the dose equivalent received by specific tissues of the body and tissue-specific weighting factors. The sum is a risk equivalent value and can be used to estimate health effects to the exposed individual. The EDE includes the CEDE (committed effective dose equivalent) from internal deposition of radionuclides and the EDE from penetrating radiation from sources external to the body. Reasonable efforts should be made to maintain radioactive releases in effluents to the environment as low as is reasonably achievable (ALARA).
- Ensure that the CEDE received by individuals who inadvertently intrude into the facility after the loss of institutional control (100 years) will not exceed 100 mrem/yr for continuous, chronic exposure or 500 mrem for a single acute exposure.

- Protect groundwater resources consistent with federal, state, and local requirements.

As indicated above, DOE Order 5820.2A provides general guidelines on how to safely dispose of LLW; however, the order does not specify (1) a time period over which they are to be applied; (2) a point of compliance; (3) which federal, state, and local requirements would be used to demonstrate that groundwater resources were adequately protected; or (4) the time and the number of people required for calculating a population dose.

C.4.1.2.5.1 Comprehensive Performance Assessments

A number of approaches have been used to demonstrate compliance with DOE Order 5820.2A. Some of these approaches have been documented in performance assessments (PAs) (systematic analyses of the potential risks posed by waste management systems to the public and environment, with a comparison of these risks to established performance objectives) of LLW management complexes (Martin Marietta, 1994; Maheras et al., 1994; Magnuson et al., 1993).

In general, the PAs derive radiological performance objectives from a combination of DOE Orders (including Order 5820.2A) and other guidance, as well as EPA regulations.

In demonstrating compliance with a combination of DOE Orders and other guidance, as well as EPA regulations, the PAs used three time periods of interest: the operational period (period of time that the facility is in operation), the institutional control period (period of time after closure in which institutional control is maintained for the facility, usually 100 years after the end of operations), and the postinstitutional control period (extending from the end of institutional control to 10,000 years in the future). If the maximum impact occurred after 10,000 years, analyses were also performed and evaluated at the time of maximum risk. EDE calculations for these times were performed at two distances: a point on the site boundary in the direction of groundwater flow downstream of the source (operational and institutional control periods), and a point 100 m downstream of the source (postinstitutional control).

Compliance with protecting the quality of groundwater is demonstrated in the PAs by showing that predicted contaminant concentrations are within guidelines specified by the EPA in the Safe Drinking Water

Act (40 CFR 141; EPA, 1991a). This compliance is usually demonstrated by showing that contaminant concentrations are below specified maximum concentration limits (MCLs) or proposed MCLs.

In addition to demonstrating compliance by showing that contaminant concentrations are below their associated MCLs, EPA's 40 CFR 141 requires that the EDE for a drinking water system (well that has at least 15 connections and serves 25 people) be below 4 mrem/yr. During operations, this well is assumed to be located at the site boundary, directly downgradient of the contaminated source. For the postinstitutional control period (10,000 years), the well is assumed to be located 100 m downgradient of the source. In either case, compliance is demonstrated by calculating the appropriate EDE, even if there is no drinking water system in place at the site.

C.4.1.2.5.2 Disposal Workgroup Performance Evaluations

Because mixed waste has a hazardous chemical component, it must be treated in compliance with land disposal restrictions (LDRs) of the Resource Conservation and Recovery Act. Because of a lack of sufficient capacity and available technologies to treat this type of waste, the Federal Facilities Compliance Act (FFCAct) of 1992 requires the Secretary of Energy to develop and submit site treatment plans (STPs) for the development of treatment capacity and technologies for treating mixed waste for each facility at which the DOE stores or generates these wastes.

Although the FFCAct does not specifically require addressing mixed waste disposal, the DOE and the States realized that the method of treatment for a specific waste is an integral component of any considerations for its ultimate disposal (Waters et al., 1996). In June 1993, DOE established the Disposal Workgroup (DWG) to work with the States to define and develop a process for evaluating LLMW disposal options. In particular, the DWG sponsored performance evaluations (PEs) at each of 15 sites (Lawrence Livermore National Laboratory, Rocky Flats Environmental Technology Site, Idaho National Engineering Laboratory, Argonne National Laboratory, Paducah Gaseous Diffusion Plant, Nevada Test Site, Los Alamos National Laboratory, Sandia National Laboratories-New Mexico, West Valley Demonstration Project, Fernald Environmental Management Project, Portsmouth Gaseous Diffusion Plant, Savannah River Site, Oak Ridge Reservation, Pantex Plant, and the Hanford Site) to quantify and compare the limitations of these sites for the disposal of LLMW (Waters et al., 1996).

For purposes of analysis and comparison, the PE teams used three primary performance measures consistent with DOE Order 5820.2A and EPA's 40 CFR 141. These performance measures are:

- 4-mrem/yr EDE from the drinking water pathway for releases to groundwater
- 10 mrem/yr for atmospheric releases
- 100 mrem/yr from all exposure pathways for chronic, long-term exposure to inadvertent intruders

For consistency, all of the calculations were performed at a performance boundary that was 100 m from the edge of the disposal facility, and all performance measures were applied for 10,000 years after disposal. This approach for demonstrating compliance is very similar to the methodology used for the comprehensive PAs. As with the PAs, the PEs do not attempt to calculate population dose.

C.4.1.2.5.3 Composite Analysis of Interacting Source Terms

In April 1996, DOE issued guidance (DOE, 1996b) on how to perform a "composite analysis" that is required by DOE pursuant to the Recommendations 94-2 from the Defense Nuclear Facilities Safety Board (DNFSB, 1994) and by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This analysis relates to LLW disposal facilities. The composite analysis is intended to supplement PAs required by DOE Order 5820.2A or risk assessments required by CERCLA.

The composite analysis will estimate the potential cumulative impacts to a hypothetical future member of the public from the active or planned LLW disposal facility and other sources of radioactive material in the ground that may interact with the LLW disposal facility. The projected total dose to a hypothetical future member of the public (receptor) from these sources will be compared with the DOE primary dose limit of 100 mrem/yr plus ALARA (as low as reasonably achievable) as set forth in DOE Order 5400.5 and proposed rule 10 CFR 834.

Under either of two conditions, an options analysis to identify alternatives for reducing future doses to tolerable limits is required. These conditions are (1) the calculated dose to the receptor exceeds the 100-mrem primary annual dose limit; or (2) the calculated dose exceeds a significant fraction of the dose limit, which is taken as 30 mrem/yr. The time of assessment is taken as 1,000 years.

The options analysis involves an ALARA process to assess cost-beneficial ways of reducing dose. The guidance discusses ways of applying an ALARA process and when an expensive, quantitative ALARA process is justified. The criterion is whether the cost of the ALARA review of alternatives is a small fraction (20%) of the monetary valuation of a possible dose reduction.

In using this criterion, the guidance suggests that the estimate of collective dose be conservative but reasonably realistic. It describes a reasonable screening process as considering the average dose from the groundwater pathway at the point of assessment to a number of individuals who might be considered to be at that point, such as the number of persons using water from a public drinking water supply system at the point of assessment. The guidance discusses that the point or points of assessment need not be in the immediate vicinity of the waste. A point of assessment should be a location where the public could be expected to have access based on future land-use plans (or conservative assumptions) and that is downgradient from the facilities that would release radioactivity to the ground.

The guidance provides that only options that could significantly reduce the dose should be considered in detail in the options analysis. Control or mitigation alternatives that might be considered include refining the analysis to reduce conservatism, improving the design of the LLW disposal facility, limiting the receipt of waste to be disposed of in the LLW disposal facility, requiring waste form performance for the waste to be disposed of at the LLW disposal facility, remediating the other sources of existing contamination, and optimizing the long-term land-use boundary. In an extreme case, termination of disposal in the LLW disposal facility may be considered. The options analysis should identify the preferred action and justify the choice based on the cost benefit analysis conducted, the level of uncertainty inherent in the composite analysis, and other relevant factors. When the 100-mrem annual dose limit is exceeded, the No Action Alternative is not acceptable.

To summarize, collective dose to a population from disposal plays a conditional role in a composite analysis. If the estimated dose to a hypothetical future member of the public does not exceed 30 mrem/yr, computation of a collective dose is not recommended. If the 30-mrem/yr value is exceeded, then the collective dose should be estimated.

C.4.2 AIR QUALITY IMPACTS

Air quality impacts were determined for pollutant-emitting activities associated with managing each of the five waste types: LLMW, LLW, TRUW, HLW, and HW. Air quality impacts were assessed for the construction of new treatment, storage, and disposal facilities; for the O&M of the facilities; and for shipment of wastes between sites. Air quality impacts were analyzed only for those pollutants for which emissions estimates were provided. The following sections describe in detail the methods used to estimate the air quality impacts for each WM alternative.

C.4.2.1 Air Quality Impacts Analysis Methods

Air quality impact assessments predict the consequences in terms of deterioration in air quality at off-site locations resulting from the release of contaminants from various categories of pollutant sources. This PEIS evaluated the potential for any of the alternative WM actions to lead to deterioration of local or regional air quality at any of the sites. The analysis also evaluated the potential for the actions across sites, in combination with pollutants emitted in the waste transportation corridors, to lead to deterioration of National air quality.

C.4.2.1.1 *Air Pollutants Considered*

The air quality impacts analysis estimated the air emissions for WM facility construction and O&M activities. O&M activities include waste treatment, storage, disposal, and transportation of waste. Estimates were made for each action for four classes of air pollutants: (1) the criteria air pollutants regulated under the National and State Ambient Air Quality Standards (NAAQS and AAQS), (2) radionuclides and other Hazardous Air Pollutants (HAPs) regulated under the National Emissions Standards for Hazardous Air Pollutants (NESHAP),

Major Types of Air Pollutants

Criteria Air Pollutants: *Carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), ozone (O_3), and particulate matter less than 10 microns in diameter (PM_{10})*

Hazardous Air Pollutants: *189 hazardous substances (including radionuclides) whose emissions are regulated by the Clean Air Act*

Toxic Air Pollutants: *Other toxic compounds regulated by EPA and state or local governments*

Ozone Depleting Substances: *Certain man-made halocarbons (including CFCs, halons, carbon tetrachloride, and 1,1,1-trichloroethane) whose manufacture and use is regulated by EPA under the Clean Air Act.*

and (3) other types of toxic air pollutants (TAPs), which are regulated by some states, and (4) ozone depleting substances (ODS), such as chlorofluorocarbons (CFCs) and halons. The analysis evaluated air quality impacts qualitatively from stationary sources and transportation sources for the first three classes of pollutants. ODS impacts are discussed qualitatively, but their emissions were not quantified.

Criteria pollutants consist of the six substances regulated by EPA (40 CFR 50) for which NAAQS have been established under the Clean Air Act (CAA): carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), ozone (O_3), and particulate matter < 10 microns (PM_{10}). They are regulated both in terms of annual production in tons per year and in terms of ambient concentrations emanating from point and mobile sources. In addition to national criteria pollutants, certain states have adopted state-regulated criteria pollutants. The state-adopted criteria pollutants are listed in the *Technical Report on Affected Environment*, Volumes I and II, for each of the DOE sites (DOE, 1995b). Unlike the other five criteria pollutants, ozone is not a direct emission but is formed in the atmosphere through a complex reaction of ozone precursor pollutants, sunlight, and temperature.

Ozone precursor pollutants include nitrogen oxides (NO_x) and nonmethane hydrocarbons. The analysis of ozone impacts was done by evaluating NO_x and volatile organic compounds (VOCs) emissions as criteria pollutants.

Hazardous air pollutants include 189 substances listed in Section 112 of the CAA of 1990 (42 USC 7401 *et seq.*), as amended through May 1992, whose emissions standards are regulated by the NESHAP in 40 CFR 61. In particular, HAPs include cancer-causing agents such as arsenic, benzene, carbon tetrachloride, and formaldehyde, as well as materials with noncancer health hazards, such as fluoride, ammonia, and hydrochloric and sulfuric acids. EPA regulates radionuclides as a total annual dose limit (10 mrem/yr) from the air pathway under the NESHAP (40 CFR 61). *Radionuclides* are also regulated by the DOE (DOE, 1990; 1993b) as a total annual dose limit (100 mrem/yr).

Toxic air pollutants include cancer causing agents and compounds with noncancer health hazards. These substances are regulated by the EPA, and on a state or local basis, through allowable ambient standards or guidelines.

Ozone depleting substances are certain man-made halocarbons, including CFCs, halons, carbon tetrachloride, and 1,1,1-trichloroethane, that react in the upper atmosphere to deplete the stratospheric

ozone layer. These compounds are regulated through the CAA and by the Montreal Protocol on Substances that Deplete the Ozone Layer.

Subsequent to December 6, 1995, HW and LLMW facilities are subject to the requirements of RCRA regulation 40 CFR Part 264, subpart AA, regarding air emission standards from process vents, and subpart BB, regarding air emission standards for process leaks. Compliance with the requirements of 40 CFR Part 264, subpart CC, regarding air emissions of volatile organic compounds from tanks, surface impoundments, and containers, was deferred until June 6, 1996 (60 FR 56952).

C.4.2.1.2 *Air Quality Impacts Analysis Procedures*

The air quality impacts analysis varied according to the pollutant classes and emissions sources expected to be important in each WM activity. Different analytical assumptions and techniques were used to best estimate the amounts of pollutants that could be emitted by each source. A summary of the air quality impacts that were evaluated in the PEIS is shown in Table C.4–7.

C.4.2.1.2.1 Analytical Approach for Different Pollutant Classes

For the air quality impacts analysis, stationary-source and area-source emissions were modeled and simple vehicular emissions factors were used to estimate mobile-source emissions for worker vehicle trips and waste transportation activities under each alternative.

C.4.2.1.2.1.1 Comparisons With Emission-Based and Concentration-Based Standards

The analysis of criteria pollutants varied according to the attainment status of a site's Air Quality Control Region (AQCR) for each pollutant. Annual emissions of the criteria pollutants from sites located in attainment areas were estimated for comparison with the allowable increment levels established in the Prevention of Significant Deterioration (PSD) regulations (40 CFR 52.21). The PSD allowable increments,

Table C.4-7. Impacts Evaluated for Air Quality

Impacts Assessed	Relevant Waste Types	Period of Analysis	Activities for Which Impacts Are Assessed	Impacts Measure	Presentation of Results
Criteria Air Pollutant Emissions	All five waste types	Construction	Use of construction equipment and worker vehicles	Percent of tons/year standard	Tabular or text discussion
		Operations	Operation of incinerators, fuel use by all other WM facilities, worker vehicles, and waste shipment vehicles, where applicable	Percent of tons/year or concentration standard	Tabular or text discussion
Radionuclide Emissions	LLMW, LLW and TRUW[a,c]	Operations[b]	Operation of WM treatment, storage and disposal facilities, where applicable	Percent of dose standard	Tabular or text discussion
Hazardous and Toxic Air Pollutant Emissions	LLMW, TRUW and HW[c]	Operations[b]	Operation of WM treatment, storage and disposal facilities, where applicable	Percent of concentration standard	Tabular or text discussion

[a] Emissions of radionuclides from HW are assumed to be negligible.
[b] Emissions assumed to be negligible during construction.
[c] Emissions of radionuclides and other hazardous and toxic air pollutants from storage of vitrified HLW are assumed to be negligible due to the physical form of the waste. Once HLW is vitrified, the glass matrix binds the radionuclides and hazardous chemicals, such that releases to the atmosphere are negligible.

in tons per year, regulate stationary-source emissions and do not include mobile-source emissions such as those from automobiles. Criteria pollutant emissions from sites located in nonattainment areas were estimated for comparison with the General Conformity Rule (GCR) guidelines *de minimis* levels, in tons per year (40 CFR 93). The GCR guidelines regulate both stationary-source and mobile-source emissions.

Ambient concentrations of the criteria pollutants were estimated for comparison with the NAAQS and State AAQS. Concentrations of the HAPs (including radionuclides) and TAPs were estimated to compare with the EPA or State ambient allowable limits (AALs).

C.4.2.1.2.1.2 Stationary-Source Estimates From Human Health Risk Modeling

In the analysis of air quality impacts from stationary-source emissions, it was assumed that ambient concentrations of criteria, hazardous, and radioactive pollutants would increase according to estimated emissions from treatment, storage, and disposal facilities and that the most conservative estimates of those increases would be the estimates of concentrations that the maximally exposed individual (MEI) would be subject to in the human health risk assessment done for this PEIS (ORNL, 1995a). Therefore, the air quality impacts analysis of stationary-source emissions used data on emissions, airborne transport and fate, and MEI doses assembled for the human health risk assessment to evaluate air quality effects. This is a conservative approach that will result in overestimating air quality impacts because the MEI doses from the health risk assessment include ingestion of farm products in addition to direct inhalation. The air quality impacts analysis used modeled estimates of local stationary-source ambient concentrations for hazardous and toxic air pollutants by waste type. Radionuclide data were taken directly from the offsite MEI doses estimated in the human health risk assessment.

C.4.2.1.2.1.3 Transportation Source Assumptions

In the air quality analysis, it was assumed that transportation sources (mobile-sources) may be an important source of criteria pollutant emissions in addition to those emanating from the facilities. Transportation sources were not expected to contribute significantly to hazardous (including radioactive) and toxic airborne contaminants in routine operations. Therefore, for criteria pollutants only, the analysis estimated local transportation-source annual tonnage of criteria pollutants, intersite transportation annual tonnage of criteria pollutants, and a national annual tonnage of criteria pollutants from all activities proposed under each alternative.

C.4.2.1.2.2 Emissions Estimation Techniques

Details of the estimation methods for construction-phase and operations-phase air emissions are presented in this section.

C.4.2.1.2.2.1 Construction-Phase Air Emissions Estimates

Emissions due to construction activities were calculated using estimates the amount of fuel used by construction equipment, and by construction workers traveling to and from the work site.

Construction Equipment Fuel Use. Fuel use in gallons of liquid fuel for the construction of WM facilities (as described in Section C.3) were used to calculate annual emissions for the WM alternatives, in tons per year, for the criteria pollutants CO, NO_2, SO_2, PM_{10}, and ozone (as NO_x and VOCs).

The fuel use values were divided by the WM alternative construction period (in years) to obtain an annual fuel usage in gallons. For the assessment of air emissions it was assumed that diesel fuel was used to operate construction equipment at the site. Emission rate factors, in pounds per gallon of fuel consumed, were obtained from *Compilation of Air Pollutant Emission Factors, Volume II, Mobile Sources*, also known as AP-42 (EPA, 1985a). The gallons of fuel used were multiplied by the pounds of pollutant per gallon consumed to obtain the annual emissions in pounds per year. This amount was divided by 2,000 pounds per ton to obtain the annual tons emitted for each of the criteria pollutants.

Worker Vehicle Fuel Use. The total number of FTEs for the construction period (as described in Section C.3) was divided by the construction period in years to obtain the total number of annual workers for each site and alternative combination. In order to provide an upper bound on air quality impacts, it was assumed that each construction worker travels to and from the construction site in a single vehicle, and that no employees carpool.

Vehicle emissions rates for the worker vehicle trips were obtained by running the EPA-approved vehicle emissions models Mobile5a (EPA, 1994a) and PART5 (EPA, 1994b). Emissions from the Mobile5a model were calculated in grams of pollutant emitted per vehicle mile traveled (VMT) for the pollutants CO, NO_2, and VOC. The PART5 model calculated PM_{10} emissions from vehicle exhaust in grams of pollutant emitted per VMT. For local impacts, it was assumed that the worker vehicles traveled 20 miles to and from work or 40 miles round trip each day. The total number of worker trips per day was multiplied by 40 miles per day and then by 240 working days per year to obtain the VMT per year. The annual VMT was then multiplied by the Mobile5a and PART5 emission rate factors in grams of pollutant per VMT to obtain the total number of grams emitted per year for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual

emissions in grams were then multiplied by 0.0022 pounds per gram and divided by 2,000 pounds per ton to obtain the annual emissions for worker vehicles in tons per year.

C.4.2.1.2.2.2 Operations-Phase Air Emissions Estimates

The impacts to air quality from the operation and maintenance of WM treatment, storage, and disposal facilities were determined by calculating the emissions from facility fuel use, incineration of waste, transportation of waste, and worker vehicle trips to and from the sites.

Waste Management Fuel Use. Facility fuel use values during the operation period of WM facilities were supplied in pounds of natural gas and gallons of liquid fuel. These fuel use values were used to calculate annual emissions for the WM Alternative, in tons per year, for the six criteria pollutants at each site under each alternative.

The fuel use values were divided by the WM alternative period (in years) to obtain an annual usage for both natural gas, in pounds, and liquid fuel, in gallons. It was assumed that both classes of fuel were burned in an industrial boiler to produce heat and steam for the WM facilities. Emission characteristics for the burning of No. 4 fuel oil, with an assumed sulfur content of 1%, were used to represent the liquid fuel.

Emission rate factors in pounds per million cubic feet for natural gas and pounds per 1,000 gallons of liquid fuel for No. 4 fuel oil were obtained from the *Compilation of Air Pollutant Emission Factors, Volume I Stationary Sources* (AP-42) (EPA, 1985b). The estimates of natural gas use, in pounds, were divided by a natural gas density of 0.0448 pounds per cubic foot to obtain a total number of cubic feet. The total number of cubic feet was then divided by 1 million to obtain the number of million cubic feet used. The number of million cubic feet used was multiplied by the pollutant emission factor, in pounds per million cubic feet, to obtain the amount of pollutant emitted in pounds per year. The total annual pounds emitted was divided by 2,000 pounds per ton to obtain the annual tons emitted for each of the six criteria pollutants.

Direct Emissions From Incinerators: Criteria Pollutants. Criteria pollutant emissions from incineration of waste were calculated for annual emissions, in tons per year, and in parts per million or micrograms per cubic meter. The annual emissions were calculated using waste volumes for treatment and pollutant emission rate data. The emission rate data were supplied for each of the six criteria pollutants in grams of

pollutant emitted per kilogram of waste incinerated. The kilograms of waste incinerated per year were multiplied by the grams of pollutant per kilogram of waste treated to obtain the total amount of pollutants emitted in grams per year. The total grams emitted per year were multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the total amount of pollutant emissions in tons per year.

Ambient concentrations of the criteria pollutant emissions were calculated by obtaining the annual emissions in grams per year, as described above, and dividing by the period of incineration operation, in seconds per year, to obtain a pollutant emission rate in grams per second. The annual emission rate in grams per second was multiplied by the highest off-site receptor concentration obtained from dispersion modeling. The dispersion model used was the EPA-approved Industrial Source Complex Long-Term Dispersion Model, Revision 2 (EPA, 1987). The model was run using an emission rate of one gram per second to produce annual receptor concentration values in micrograms per cubic meter per one gram per second ($\mu g/m^3/g/s$). To obtain a new concentration value for a different emission rate, the normalized concentration was multiplied by the new emission rate; the new concentration value was in micrograms per cubic meter ($\mu g/m^3$). The new annual concentration was divided by averaging period persistence factors, obtained from the EPA document *Air/Superfund National Technical Guidance Study Series, Screening Procedures for Estimating the Air Impacts of Incineration at Superfund Sites* (EPA, 1992a), to produce short-term concentrations for different averaging periods. These concentration values were compared to the NAAQS or State AAQS pollutant specific averaging periods as appropriate.

Direct Emissions From Incinerators: Hazardous and Toxic Air Pollutants. Annual exposure concentrations of HAPs and TAPs, in $\mu g/m^3$, to the off-site MEI were obtained from the human health risk assessment (Appendix D). For comparison of the HAPs and TAPs concentrations to State or EPA AALs, the concentrations were multiplied by the appropriate AAL averaging period persistence factor. The HAPs concentrations were divided by the AALs to obtain the percentage of the HAPs to the AALs.

The following four AAL guidelines were used; State, EPA Region III, EPA Region IX, and EPA long-term action level. The order in which the different guidelines were applied was as follows: the state guideline was applied in all cases where the state had established guidelines; for those states with no adopted guidelines and located in either EPA Region III or IX, the EPA Region guidelines were applied; for those states with no guidelines which were not located in either EPA Region III or IX, the EPA long-term action levels were applied.

Worker Vehicle Fuel Use. The total number of FTE employees for the waste treatment period was divided by the treatment period in years to obtain the total annual number of workers for each site and WM alternative. It was assumed (with the exception of Hanford) that each worker travels to and from the site in a single vehicle each day. For Hanford, the worker trips were adjusted to account for the percentage of employees who participate in ride-sharing programs. A worker trip reduction value of approximately 19% was obtained from the *FY 1993 Annual Report on In-house Energy Management* (Kaiser Engineers Hanford and Westinghouse Hanford Company, 1994), and applied to all Hanford worker trip numbers.

Vehicle emissions rates for the worker vehicle trips were obtained by running the EPA-approved vehicle emissions models Mobile5a and PART5. Emissions from the Mobile5a model are calculated in grams of pollutant exhaust per VMT for the pollutants CO, NO_2, and VOC. The PART5 model calculated PM_{10} emissions from vehicle exhaust in grams of pollutant emitted per VMT.

For local impacts, it was assumed that the worker vehicle traveled 20 miles to and from work, or a round trip distance of 40 miles per day. The total number of worker trips per day was multiplied by 40 miles per day and then by 240 working days per year to obtain the total VMT per year. The annual VMT was multiplied by the Mobile5a and PART5 emission factors in grams of pollutant per VMT to obtain the total number of grams emitted per year for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the annual emissions for worker vehicle trips in tons per year.

Indirect Emissions From Waste Shipments. Air emissions from shipment of waste from site to site (intersite), and to commercial waste handlers for HW, were calculated for local and national impacts. Local impacts were calculated for the site region of influence (ROI) (defined as a 50-mile radius), while intersite impacts were calculated based on the mileage traveled between sites, excluding the emissions calculated locally in the 50-mile radius. The intersite shipment emissions represent the contributions to regional or national levels of the criteria air pollutants, which are not accounted for in the site analysis.

The total number of waste shipments entering and leaving each WM site for the treatment period was obtained from ANL-E. The number of shipments per treatment period was then divided by the length of the treatment period in years to obtain the total number of shipments to and from the site on an annual basis.

Vehicle emissions rates for the truck shipments were obtained by running the EPA approved vehicle emissions models Mobile5a and PART5 as described above.

For local impacts the shipment miles were calculated using a travel distance of 50 miles to and from the site, or a round trip of 100 miles. The annual shipment numbers were multiplied by 100 miles to obtain the total annual VMT. The annual VMT was then multiplied by the Mobile5a and PART5 emission rate factors, in grams of pollutant per VMT, to obtain the total annual number of grams emitted for the criteria pollutants CO, NO_2, VOC, and PM_{10}. The annual emissions in grams were then multiplied by 0.0022 pounds per gram and then divided by 2,000 pounds per ton to obtain the annual emissions for shipment by truck in tons per year.

Radiation Dose Estimates. Total radiation dose values, in rem, were obtained from the human health risk assessment for the MEI at an offsite location. The total dose values in rem were multiplied by 1,000 to obtain the dose in millirem (mrem). The dose was then divided by the period of operation (10 or 20 years) and compared to the NESHAP dose standard of 10 mrem per year.

C.4.2.1.3 *Air Quality Impacts Evaluation*

In general, air quality impacts were evaluated by comparing estimated emissions and concentrations to 10% and 100% of Federal or State standards.

C.4.2.1.3.1 Impacts Evaluation for Criteria Pollutants

Criteria pollutant effects were assessed based on the air quality *attainment status* of each site's AQCR, for each of the six criteria pollutants. In general, the site's applicable AQCR is in attainment for a particular criteria pollutant if monitored ambient levels are below the NAAQS for that pollutant. The site's applicable AQCR is a nonattainment area for a particular criteria pollutant if ambient levels equal or exceed the NAAQS for that pollutant. The attainment status of the DOE sites for the NAAQS criteria pollutants are listed in Table C.4–8. Table C.4–9 explains the nonattainment status designations.

Table C.4-8. Criteria Pollutant Attainment Status at the 17 Major Sites

Site	State	NAAQS Attainment Status					
		CO	NO_2	O_3	Pb	PM_{10}	SO_2
ANL-E	IL	A	A	S-17	A	MOD	A
BNL	NY	A	A	S-17	A	A	A
FEMP	OH	A	A	MOD	A	A	A
Hanford	WA	A	A	A	A	A	A
INEL	ID	A	A	A	A	A	A
LANL	NM	A	A	A	A	A	A
LLNL	CA	A	A	A	A	A	A
NTS	NV	MOD-2	A	A	A	MOD	A
ORR	TN	A	A	A	A	A	A
PGDP	KY	A	A	MAR	A	A	A
PORTS	OH	A	A	A	A	A	A
Pantex	TX	A	A	A	A	A	A
RFETS	CO	MOD-2	A	TRANS	A	MOD	A
SNL/NM	NM	MOD-1	A	A	A	A	A
SRS	SC	A	A	A	A	A	A
WIPP	NM	A	A	A	A	A	A
WVDP	NY	A	A	A	A	A	A

Notes: CO = carbon monoxide; NO_2 = nitrogen dioxide; O_3 = ozone; Pb = lead; PM_{10} = particulate matter < 10 micrometers; SO_2 = sulfur dioxide; A = attainment; nonattainment codes: S-17 = severe-17; MOD-2 = moderate-2; MOD-1 = moderate-1; MOD = moderate; MAR = marginal; TRANS = transitional.

Source: 40 CFR 81, Subpart C: Section 107 *Attainment Status Designations* (1992), except LLNL, which is based on 1995 data.

C.4.2.1.3.1.1 Impacts for Installations in Attainment Regions

Any predicted increases to ambient concentration levels in areas designated as attainment by the EPA were compared to the NAAQS. If the estimated ambient concentrations exceeded the NAAQS then that WM alternative and the affected area were noted in the PEIS.

The annual criteria emissions, in tons per year, were compared to the allowable increase levels specified in 40 CFR 52.21, Regulations for the PSD of Ambient Air Quality. PSD regulations are applicable in those

Table C.4–9. Nonattainment Status Definitions[a]

Criteria Pollutant	Nonattainment Designation	NAAQS Exceedance Range
Carbon monoxide (CO)	Moderate-1	9.1 to 12.7 ppm
	Moderate-2	12.8 to 16.4 ppm
Ozone (O_3)	Marginal	0.121 to 0.138 ppm
	Moderate	0.138 to 0.160 ppm
	Severe-17	0.190 to 0.280 ppm
Particulate matter (PM_{10})	Moderate	Greater than NAAQS

[a] Only the nonattainment status designations used in Table C.4–8 are shown.

areas which are listed as in attainment of the NAAQS for each of the criteria pollutants. These allowable increases are referred to in the PSD regulations as PSD increments and PSD significant emission levels (SELs). If the estimated annual emissions exceeded the allowable PSD SELs increments, then that WM alternative and the affected area were noted in the PEIS. The air analysis only compared annual emissions to PSD SELs to determine whether a site could exceed the SELs and an action at a particular site could trigger a PSD review. The analysis should not be interpreted as being a refined PSD analysis. A refined PSD analysis would need to be performed prior to installation of any action at a potential PSD site. PSD increases account for all stationary-source emissions that can be reasonably attributed to the action but do not account for emissions from mobile sources. PSD increases for attainment areas are listed in Table C.4–10.

C.4.2.1.3.1.2 Impacts for Installations in Nonattainment Regions

New stationary sources or major modifications of existing sources located in *nonattainment* areas for criteria pollutants must conform to New Source Performance Standards for new, or modified, existing pollutant sources. In addition, Federal actions which are located in nonattainment areas are required to follow the GCR guidelines (40 CFR 93) in determining the conformity of the action to Section 176(c) of the CAA and to approved State or Federal implementation plans. The GCR establishes specified *de minimis* levels for criteria pollutant emissions, in tons per year, based on the AQCR's nonattainment designation. Actions producing emissions which are below the *de minimis* levels are considered to conform, while those equal to or above the limits are required to perform a conformity determination as outlined in the GCR. The GCR

Table C.4–10. PSD Increments for Criteria Pollutant Emissions in Attainment Areas

Pollutant	Tons/Year
Carbon monoxide (CO)	100
Nitrogen dioxide (NO_2)	40
Ozone (as VOC)	40
Lead (Pb)	0.6
Particulate matter	25
Particulate (PM_{10})	15
Sulfur dioxide (SO_2)	40

Source: 40 CFR 52.21.

accounts for all stationary-sources and mobile sources of emissions that can be reasonably attributed to the action. GCR limits for criteria pollutants in nonattainment areas are listed in Table C.4–11.

C.4.2.1.3.2 Impacts Evaluation for Hazardous (Including Radionuclides) and Toxic Air Pollutants

The determination of applicable emissions limits and allowable ambient concentrations for pollutants other than the six criteria pollutants, was performed on a site-by-site basis. This approach was necessary because site-specific information on existing levels of noncriteria contaminants was not readily available from the site or regulatory agencies. Information on ambient concentrations of such substances from DOE site monitoring and environmental impact statements was used when available and applicable. In addition, the applicable regulations and standards vary considerably from state to state. Detailed procedures were defined on a site-by-site basis and described in the pertinent site air quality analyses section in the PEIS waste-type chapters.

Table C.4-11. General Conformity Rule de minimis Levels for Nonattainment Areas

Pollutant and Nonattainment Designation	*de minimis* Level (tons/year)
Ozone (Volatile Organic Compounds or Nitrogen Oxides):	
- Serious Nonattainment Areas	50
- Severe Nonattainment Areas	25
- Extreme	10
- Other ozone Nonattainment Areas (outside an ozone transport region)	100
- Marginal and moderate Nonattainment Areas (inside an ozone transport region)	
VOC	50
NO_x	100
Carbon Monoxide (CO):	
- All Nonattainment Areas	100
Sulfur Dioxide (SO_2) or Nitrogen Dioxide (NO_2):	
- All Nonattainment Areas	100
Particulate Matter <10 microns (PM_{10}):	
- Moderate Nonattainment Areas	100
- Serious Nonattainment Areas	70
Lead (Pb):	
- All Nonattainment Areas	25

Source: 40 CFR 51.

C.4.2.1.3.3 Impacts Evaluation for Ozone Precursor Emissions.

Ozone pollution is generally caused by reactions between VOC and NO_x, in the presence of sunlight, and generally reaches its maximum many miles downwind of the sources of these substances. The impacts of the WM alternatives on ambient ozone levels were assessed by comparing changes in emissions of VOC and NO_x with the total rate of emissions of these substances from the DOE site, the county, or the AQCR in which the emissions occur. It was assumed that changes in ozone precursor emissions would result in corresponding changes in downwind ozone levels.

C.4.2.1.3.4 Ozone Depleting Substances

The stratospheric ozone layer protects the earth from the penetration of harmful ultraviolet radiation. On the basis of substantial scientific evidence, a national and international consensus currently exists that certain man-made halocarbons (including CFCs, halons, carbon tetrachloride, and methyl chloroform), react in the upper atmosphere to deplete the stratospheric ozone layer.

In response to this awareness, the United States and 22 other countries in 1987 signed the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol, as originally drafted, called for a freeze on the production of CFCs at 1986 levels and for CFCs to be reduced by 50% by 1998.

The CAA, as amended, includes requirements for controlling ozone depleting substances that are generally consistent with, but in some cases, more stringent than those contained in the Montreal Protocol. Title VI of the CAA, and the implementing regulations (40 CFR 82), call for a phaseout of CFCs by January 1, 2000. In addition to the phaseout of ODS, Title VI includes a variety of other provisions intended to reduce emissions of ODS and promote the recycling of these substances. In addition, DOE facilities are required to adhere to Executive Order 12843 of April 23, 1993: *Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances*. This Executive Order stipulates that all Federal Agencies must implement cost-effective programs to minimize the procurement of materials and substances that contribute to the depletion of stratospheric ozone; and give preference to the procurement of alternative chemicals, products, and manufacturing processes that reduce overall risks to human health and the environment by reducing the depletion of ozone in the upper atmosphere.

Impacts to the stratospheric ozone layer due to emissions from WM activities were estimated. The analysis was performed at the alternative level since emissions of ozone depleting substances is a global rather than a site issue. The analysis was performed for waste types where treatment of waste containing hazardous constituents occurs (i.e., LLMW, TRUW and HW). The compounds analyzed include the ozone depleting substances identified by EPA in 40 CFR 82. Emissions of ozone depleting substances from incineration were tallied from information supplied by the health risk assessment. The total emissions from each alternative were found to be exceedingly small for all waste types, and in fact were <0.1 pound per year for all LLMW alternatives (DOE, 1996a). These minor emissions would not be expected to have any measurable affect on upper atmosphere ozone levels. Emissions of ozone depleting substances from other

treatment, storage and disposal operations were assumed to be small due to the nature of these activities, and the mandated phase-out of the use of ozone depleting substances.

C.4.3 WATER RESOURCES IMPACTS ANALYSIS METHODS

This section describes the methods used to estimate the impacts of proposed WM alternatives on surface water and groundwater resources. Section C.4.3.1 provides an introduction, C.4.3.2 briefly describes the regulations that limit impacts to water resources, C.4.3.3 lists the assumptions used in the impacts analyses, C.4.3.4 describes impacts that were considered but not evaluated in detail, and C.4.3.5 describes the methods used to assess the impacts on water resources that were evaluated in detail.

C.4.3.1 Introduction

The alternatives analyzed in this PEIS can affect the quantity or the quality of surface water and groundwater. Water availability elements that may be affected include surface water flow, floodplains, groundwater flow, and aquifer water levels. Surface water and groundwater rights, allocations and usage may also be affected. Water quality elements that may be affected include areas of surface water and groundwater that are already contaminated, and receiving water bodies such as streams, lakes, rivers, and groundwater aquifers. The ROI for water resources is the area encompassed by onsite and offsite surface water and groundwater bodies and their watersheds, which may be affected by site activities.

Water availability is affected when water withdrawal or discharge causes an appreciable change in surface water flow or groundwater levels. Water quality is affected when discharges cause an appreciable increase in the concentration of sediments or contaminants in the receiving water body. In addition, water quality may be affected when activities cause the movement of existing contamination. For example, activities that change the water table gradient could accelerate offsite movement of a plume of groundwater contamination.

Construction, operation, and transportation activities can adversely affect water resources, both during normal operations and when an accident occurs. Waste management activities may adversely affect surface and groundwaters, as a result of increased water use, increased stormwater runoff, increased wastewater discharges, and releases to groundwater from disposal facilities. Transportation of wastes may affect water

resources from the deposition of exhausts emitted from the vehicles and from accidental spills into water bodies.

C.4.3.2 Regulatory Considerations

The Clean Water Act (33 USC 1251 *et seq.*), as amended, requires a permit for all discharges to surface waters (including stormwater discharges) under the National Pollutant Discharge Elimination System (NPDES) program. NPDES permits set discharge limits for contaminants and require periodic monitoring to ensure compliance. In addition, Section 404 of the Clean Water Act regulates the discharge of fill material into navigable waters of the United States.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC 9601 *et seq.*), as amended, requires the cleanup of contaminated areas and specifies cleanup levels by application of Applicable or Relevant and Appropriate Requirements (ARARs).

The Safe Drinking Water Act (42 USC 300 *et seq.*) regulates drinking water quality. The maximum contaminant levels established in the implementing regulations (40 CFR 141), although not directly applicable to groundwater quality, are commonly used as ARARs to determine appropriate levels for groundwater cleanup. Since the drinking water standards adequately protect human heath, concentrations of contaminants in groundwater at or below these levels present a low risk. In addition, DOE derived concentration guides for drinking water (DOE, 1990) are sometimes cited as "to be considered" requirements under CERCLA.

Executive Order 11988 (Floodplain Management) and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements) require that proposed projects be reviewed to determine their impact on floodplain and wetland areas. Federal agencies are required to avoid, when possible, occupying and modifying floodplains. Floodplain and wetland assessments are required for actions that occur within the 100-year floodplain, and for "critical actions" that occur within 500-year floodplains.

Monitoring of effluents and nearby water bodies for adverse effects from WM facilities is required by a number of statutes and their related regulations. Under the Clean Water Act, the NPDES requires that discharges to waters of the United States be monitored and that levels of contaminants in the effluent remain

below permitted levels. The Clean Water Act, as amended, also requires stormwater discharges to be monitored. The regulations implementing the RCRA (42 USC 6901 *et seq.*) have extensive requirements for groundwater monitoring at hazardous waste treatment, storage, and disposal facilities. Levels of contaminants in the groundwater must remain below levels described in the regulations. The regulations of the Toxic Substances Control Act (15 USC 2601 *et seq.*) require similar monitoring at treatment, storage, and disposal facilities for asbestos and polychlorinated biphenyls (PCBs). DOE orders (e.g., 5820.2A [DOE, 1988]), require surface water and groundwater monitoring at radioactive waste treatment, storage, and disposal facilities. In addition, EPA regulations (40 CFR 191) require monitoring of treatment, storage, and disposal facilities at DOE sites that dispose of HLW and TRUW.

Monitoring generally involves periodic measurement of characteristics of the effluent or receiving water body including measurement of radionuclide and chemical concentrations, temperature, pH, and flow. Groundwater monitoring usually involves the analysis of samples collected from wells drilled for this purpose. Surface water monitoring generally involves sampling from stations located downstream from the effluent discharge point. These monitoring stations are located such that they are likely to intercept any releases from a WM facility.

Monitoring provides the opportunity to detect excessive discharges from a WM facility before significant harm is done to human health or the environment. Once the cause of the excessive discharge is located, corrective actions are implemented to contain and then eliminate the source of the problem. DOE will comply with all applicable monitoring requirements.

C.4.3.3 Assumptions

Assumptions for the water resources impacts analysis included the following:

- Current conditions of water resources adequately represent future baseline conditions.
- Water for WM activities would be supplied by current water sources. If water is currently supplied by wells in aquifer X, water for the proposed alternatives would be supplied by wells in aquifer X. If water is currently supplied by a municipal system, then water for the proposed alternatives would be supplied by that system. If water is currently supplied by river Y, water for new facilities would be supplied by river Y.

- Because municipal water is used as the current source, onsite surface water and groundwater resources would not be affected by water withdrawals at Rocky Flats Environmental Technology Site (RFETS), Sandia National Laboratories-New Mexico (SNL/NM), and Waste Isolation Pilot Plant (WIPP). Because groundwater is used as the current source, impacts to surface water resources are likely to be small as a result of groundwater withdrawals at Argonne National Laboratory-East (ANL-E), Brookhaven National Laboratory (BNL), Fernald Environmental Management Project (FEMP), INEL, Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL) Site-300, Nevada Test Site (NTS), Pantex Plant, Portsmouth Gaseous Diffusion Plant (PORTS), and SRS. Because surface water is the current source, impacts to groundwater resources are likely to be small as a result of surface water withdrawals at Hanford, Oak Ridge Reservation (ORR), Paducah Gaseous Diffusion Plant (PGDP), and WVDP.
- Although some sites under consideration receive water from more than one source, they are assumed to obtain their water as follows: (1) Hanford Site from surface water; and (2) LLNL Site-300 and SRS from groundwater. Since only a small portion of the Hanford Site is supplied by groundwater, it was assumed that all water would be supplied by surface water. At LLNL Site-300, water is supplied by an offsite municipal source and onsite groundwater, but to be conservative, it was assumed that groundwater supplied all the water to the site. At SRS, surface water is generally used only for cooling water. Therefore, it was assumed that groundwater would be used to supply WM facilities.
- During normal operations, no untreated sanitary or process wastewater would be discharged to surface or groundwaters at any site. Wastewater would be recycled to the extent possible and then discharged to existing process or sanitary treatment plants, as appropriate. After treatment, wastewater would be discharged from these plants in compliance with all NPDES and industrial wastewater discharge permits.
- Sanitary wastewater treatment capability was not included among the new WM facilities to be constructed. Therefore, it was assumed that sanitary wastes would be discharged to existing plants. New capability to treat process wastewater was included for WM facilities to be constructed.
- The manner of disposing wastewater would not change. If wastewater is currently discharged to a municipal sewer system, than future wastewater would be discharged to that system. If wastewater is currently discharged to a treatment plant, effluent would continue to be discharged to the treatment plant.
- Since the locations for the WM have not been selected, it was not possible to determine which particular onsite water course(s) would be affected. For this impacts assessment, the major offsite water body was assumed to be the receiving water body.

- Onsite surface water resources would not be affected by effluent discharges at SNL/NM, because wastewaters are discharged to municipal wastewater treatment systems. Surface water resources would not be affected by effluent discharges at Hanford, INEL, LANL, LLNL Site-300, NTS, Pantex, or WIPP, because generally, wastewaters are discharged to dry stream beds or man-made ponds, and not to natural-flowing surface water bodies.
- For municipal water supply systems, withdrawals up to the capacity of the site distribution system are acceptable. It was assumed that, if water is available from the utility, the necessary steps have been taken to ensure that operations meet Federal, State, and local environmental regulations. These steps may include withdrawal permits, water rights agreements, and environmental impact reports. This same assumption applies to municipal wastewater treatment.
- During normal operation of waste storage facilities, no water (including precipitation, surface water, or groundwater) would be allowed to come into contact with the waste. Therefore, surface and groundwater quality would not be affected because runoff would not be contaminated. During normal operation of waste treatment facilities, no releases directly to groundwater would occur. Therefore, groundwater quality is not likely to be affected.
- Seepage of contaminated groundwater from disposal facilities could contaminate surface water. This contamination would be diluted by surface water flows such that the concentration in the surface water would be less than the concentration in the groundwater.
- As described in Appendix E, for waste transported in U.S. Nuclear Regulatory Commission (NRC) Type B certified containers, the probability of container leakage during an accident would be very low. Therefore, transportation accidents involving Type B containers were assumed not to affect surface or groundwater resources.

C.4.3.4 Impacts Considered but Not Evaluated in Detail

This section describes potential impacts to water resources that were not evaluated in detail in the PEIS. These impacts were not evaluated in detail because they (1) could be evaluated generically rather than for each alternative; (2) are believed to be minor; or (3) require site-specific analyses that are not possible at this time.

C.4.3.4.1 *Impacts to Floodplains*

If possible, new WM facilities would be located outside the 100-year floodplain, and if the facilities are considered "critical actions," would be located outside the 500-year floodplain. As a minimum, facilities managing LLMW or HW would be required to meet additional design criteria and/or siting requirements to obtain an RCRA permit. Even if the WM facilities are located outside floodplains, access roadways and utility corridors may encroach on floodplains. The impacts of these activities cannot be estimated at this time since the specific locations of the WM facilities have not been selected. Compliance with floodplain and wetland review requirements, including Executive Order 11988 (Floodplain Management) and 10 CFR 1022 (Compliance with Floodplain/Wetland Environmental Review Requirements), would be examined in detail when specific locations are proposed during sitewide or project-specific NEPA reviews.

C.4.3.4.2 *Impacts From Runoff and Sedimentation*

During the construction period, surface water resources could be affected by runoff and sedimentation from site clearing. During operations, water resources could be affected by increased runoff from buildings, parking lots, and cleared areas. Generally, the impacts would be proportional to the amount of land disturbed during construction or occupied during operations. In all cases, the effects would be minimized by implementing the best management practices for stormwater runoff and erosion control. These practices include the use of silt fences, runon and runoff diversion ditches, and stormwater retention and sedimentation ponds. In addition, stormwater discharges would be regulated by the new NPDES stormwater discharge permits. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary, these impacts would be evaluated in sitewide or project-specific NEPA documents.

During WM operations, stormwater runoff may be contaminated with small quantities of materials deposited from air-borne emissions. Some of the potentially contaminated stormwater runoff would be contained within onsite stormwater collection ponds. The stormwater runoff would evaporate or infiltrate into the ground, although the ponds may discharge to surface water bodies during high flow conditions. The volume of stormwater in the ponds would be expected to change somewhat between the alternatives, depending on the size of the areas drained, but the quality of the water would be expected to be similar. Stormwater runoff would be routinely monitored and any discharges would be in compliance with site-specific permit

limits. The impacts of runoff were not evaluated in quantitative fashion but were assumed to be low due to regulations and practices for erosion control and stormwater management. Impacts from stormwater runoff are highly site-specific and would be considered in NEPA documents tiered to the WM PEIS.

Stormwater runoff that is not contained within the stormwater management system may contaminate surface waters. This runoff may contain small amounts of contamination from airborne emissions. Controls would be implemented at each site to minimize the potential for contaminated stormwater runoff. Impacts from contaminated stormwater runoff are expected to be minor, but are highly site-specific and would depend on the design of the stormwater management system, meteorologic conditions, topography, soil, and the affected surface water body at the site. These impacts should not influence the choice of alternatives, but would be considered in sitewide or project-specific NEPA documents if necessary.

C.4.3.4.3 *Impacts From Sanitary Wastewater Discharges*

The majority of any new aqueous waste would be sanitary waste generated by the employees needed for the alternative. Sanitary wastes by definition are nonhazardous and would be discharged to existing sanitary wastewater treatment facilities. After treatment, sanitary wastewaters would be recycled, or discharged from these plants in compliance with site-specific NPDES, or industrial wastewater discharge permit limits. Limits on the amount of contaminants in the effluent are set by the regulators after consideration of potential adverse ecological and human health effects in the receiving water body. The impacts on existing sanitary wastewater treatment facilities are discussed in the infrastructure sections of each waste-type chapter.

Although the volume of sanitary wastewater may vary between alternatives, it would remain similar in quality. Therefore, current conditions would not change appreciably unless the discharge volume was a large percentage of the flow in the receiving water body. The impacts of combined sanitary and process wastewater discharges on surface water availability were evaluated for all waste types in the site tables, and show only minor (less than 1%) changes in flow. Since the quality of effluent discharges from sanitary wastewater treatment facilities would not change, and the flow would not be a significant fraction of the average flow in the major receiving water body, current monitoring captures the majority of the water quality effects of sanitary wastewater treatment plant discharges for the alternatives. Therefore, impacts from these activities are not expected to be major, and should not influence the choice of alternatives. If necessary, these impacts would be considered in sitewide or project-specific NEPA documents.

C.4.3.4.4 *Impacts From Process Wastewater Discharges*

Process wastewater is wastewater potentially contaminated by hazardous or radioactive constituents during treatment, storage, or disposal activities. In the WM PEIS, it was assumed that easy-to-treat and hard-to-ship wastes, such as aqueous wastes and slurries (process wastewater), would be treated at the generating site and would not be shipped off site for treatment. After treatment, wastewaters would be recycled or discharged in compliance with site-specific DOE, NPDES, or industrial wastewater discharge limits. Because process wastewater treatment would continue at the sites where it presently occurs and because the volumes of process wastewater treated at each site would vary only slightly between alternatives, the effects of process wastewater treatment on surface water and groundwater quality are largely accounted for in the affected environment section. Therefore, the impacts from these activities should be similar for all alternatives and should not influence the choice of alternatives. If necessary, these impacts would be evaluated in sitewide or project-level NEPA documents.

C.4.3.4.5 *Impacts to Small Onsite Streams*

Wastewater released by WM facilities may enter small onsite water courses before entering the major surface water body near the site. Additional effluents in these small streams, may cause eroding of parts of the stream channel and sedimentation in other parts of the channel. Water quality may also be affected because the facility effluents may form a large fraction of the natural streamflow. Before NPDES permits are renewed or issued by the EPA or state agencies, water quality in the receiving water body would be considered in setting effluent limits for the facilities. Impacts on small onsite water bodies would be considered in detail in sitewide or project-specific NEPA documents.

C.4.3.4.6 *Impacts of Water Withdrawals on the Movement of Groundwater Contamination*

Withdrawals of groundwater for use by WM facilities could cause the movement of existing areas of groundwater contamination. This could occur where water levels are lowered by water withdrawals. Impacts of this sort are unlikely because existing wells would be used to the extent possible, and new wells would be located to minimize their impact on the movement of existing contaminant plumes. Impacts on

existing areas of contamination would be considered in detail in sitewide or project-specific NEPA documents.

C.4.3.4.7 *Impacts From Waste Disposal on Surface Water Quality*

Seepage of contaminated groundwater from disposal facilities could contaminate surface water. This would be expected to occur at sites with shallow groundwater, and surface water bodies that are fed by groundwater discharge (springs). Some sites (INEL, NTS, and Pantex) are located above deep groundwater such that surface water would not be expected to become contaminated. Other sites (LANL, LLNL, SNL/NM, and WIPP) have a low potential for surface water contamination due to the intermittent nature of most of the sites streams. Where contaminated groundwater discharges to the surface, dilution in "clean" surface waters would cause concentrations of contaminants in surface water to be lower than concentrations in groundwater. Therefore the groundwater pathway was assumed to be the major pathway for movement of contaminants beyond the disposal facility boundary, and was the pathway that was examined in detail.

C.4.3.4.8 *Impacts From Transportation*

Routine transportation would involve the intersite movement of waste by truck or rail, and the travel of workers to and from work. Waste materials would not be released during routine transportation of wastes. Therefore, impacts from transportation would be limited to the deposition and runoff of vehicle emissions to surface waters and the infiltration of materials deposited on the surface into groundwaters. As described in Section C.4.2 on air quality, vehicle emissions at any one place from transportation would be small. Therefore, the impacts of routine transportation on surface and ground waters would be minimal.

C.4.3.4.9 *Impacts From Transportation Accidents*

Because the waste would be shipped in sealed NRC or DOT approved containers, impacts to water resources would be unlikely unless a ruptured container fell directly into a surface water body. In the unlikely event that waste was released from a shipping container, cleanup response to the accident would be swift, and the release would be contained and cleaned up as quickly as possible. The spill response and

cleanup, and any subsequent remediation, would be conducted in accordance with the CERCLA as amended, the National Oil and Hazardous Substances Pollution Contingency Plan, and DOE emergency response requirements. Since a swift cleanup would occur, long-term impacts to water quality are unlikely. Potential short-term impacts on water quality and on aquatic resources are addressed in Sections 7.7.5 and 8.7.5 of Volume I.

C.4.3.4.10 *Vulnerability of Sites to Surface Water Impacts*

The primary water-related impacts of WM activities are likely to be through groundwater. Nevertheless, there may be sites at which WM activities could cause surface water impacts. This section provides a qualitative assessment of the vulnerability of sites to surface water impacts. The approach used here is to identify some of the key factors that could contribute to surface water impacts and identify those sites at which surface water may be an important pathway for movement of contaminants offsite. It is important to recognize that these sites are not pristine areas, but are already the source of some pollutants that potentially affect the surrounding surface water bodies.

Table C.4–12 provides information on:

- Average annual precipitation, which gives an indication of the likelihood for pollutants to be transported offsite through stormwater runoff
- The major surface water bodies near each site, their distance from the site, and their average flow rate, which indicates the relative importance of the surface water body and the likely impact on it of contaminants from the WM activities
- The presence of groundwater discharge to surface water bodies near the site, which indicates a mechanism other than direct discharge by which WM activities could impact surface water quality
- The presence of nearby surface water supply intakes downstream from the site, which indicates the potential exposure of human populations

Several of the sites are in arid to semiarid climates with limited rainfall and have no discharges to major surface water bodies (i.e., INEL, NTS, Pantex, and WIPP). Site wastewater discharges and stormwater runoff are unlikely to reach major surface water bodies, and little or no groundwater discharges into streambeds. These characteristics make it unlikely that WM activities would produce major surface water impacts near these sites.

Table C.4–12. Key Factors Contributing to Surface Water Impacts

Site	Average Annual Precipitation (cm)[a]	Major Surface Water Bodies			Presence of Groundwater Discharge to Surface Water Onsite or near Site Boundary[b]	Presence of Nearby Drinking Water Supply Intakes Downstream from Site[b]
		Major Surface Water Bodies Within 10 Miles of Sites[b]	Distance to Major Surface Water Bodies[b]	Average Flow Rate of Major Surface Water Bodies Near Sites (gpd)[b]		
ANL-E	80	Des Plaines River	<1 mile	582 million	Yes	No
BNL	107	Peconic River	Onsite	1 million	Yes	No
FEMP	104	Great Miami River	<1 mile	1.823 billion	Yes	No
Hanford	16	Columbia River	Onsite	77.560 billion	Yes	Yes
INEL	23	None[c]	NA	NA	No	No
LANL	47	Rio Grande	At site boundary	1.727 billion	Yes	No
LLNL-Livermore	36	None[c]	NA	NA	No	No
LLNL-Site 300	36	None[c]	NA	NA	Yes	No
NTS	19	None[c]	NA	NA	No	No
ORR	139	Clinch River	At site boundary	3.003 billion	Yes	Yes
PGDP	120	Ohio River	<2 miles	174.521 billion	Yes	No
Pantex	51	Onsite playa basins that do not connect with offsite surface water bodies	NA	NA	No	No
PORTS	101	Scioto River	<1 mile	3.036 billion	Yes	No
RFETS	38	Walnut Creek	Onsite	142 million	Yes	Yes; but all onsite discharges are diverted around water supply
SNL-NM	20	Rio Grande	6 miles from edge of Kirtland AFB	651 million	Yes	No
SRS	122	Savannah River	At site boundary	6.463 billion	Yes	No
WIPP	31	None[c]	NA	NA	No	No
WVDP	104	Buttermilk Creek	Onsite	41 million	Yes	No

Note: NA = not applicable.
[a] Data from DOE (1996a).
[b] Data from DOE (1995b).
[c] Stream channels are dry for most of the year.

At three other sites with arid to semiarid climates (LANL, LLNL, and SNL-NM), discharges off site occur uncommonly and are made up largely of stormwater runoff or snowmelt. At these sites, groundwater can seep into the beds of the intermittent streams at times during the year. These characteristics also make it unlikely that WM activities would cause major surface water impacts near these sites.

At RFETS, annual average precipitation is also low, although groundwater discharges into the nearby creeks. Parts of the site originally drained via small creeks to two reservoirs that are used for drinking water supplies by the towns of Broomfield and Westminster. Since 1989, all discharges from the RFETS are contained in onsite manmade ponds and diverted to the Broomfield Diversion Ditch, which bypasses the reservoirs and discharges to Walnut Creek downstream from the reservoirs. Although past activities at RFETS have impacted surface water resources, it is unlikely that major impacts to surface waters would occur from the incremental addition of WM activities.

ANL-E, FEMP, Hanford, ORR, PGDP, PORTS, and SRS are near major water bodies that have large to very large average flows. Groundwater at these sites recharges into the nearby streams and rivers. These characteristics indicate that although some impacts to surface water are likely to occur near these sites, it is unlikely that major surface water impacts would occur.

BNL and WVDP are near water bodies with small to medium average flows. During wet periods groundwater discharges to onsite streams. While these sites are more vulnerable to surface water contamination than are the sites discussed in the previous paragraphs, in the near term surface water impacts from the incremental addition of WM activities are not expected to be major. As described in the Draft WVDP closure EIS, significant impacts to surface water could occur in the future if erosion breaches the waste disposal facilities.

Most of the sites do not have downstream water supply intakes nearby, although there are nearby water supply intakes downstream from Hanford, ORR, and RFETS. At RFETS site discharges are routed around the water supply reservoirs and at Hanford and ORR the large surface water bodies provide a great deal of dilution of any contaminants released from the sites; therefore, major impacts to downstream drinking water supplies from WM activities at these sites are unlikely.

Impacts on surface water resources and drinking water supplies would be considered in sitewide or project-specific NEPA documentation, after the locations of WM facilities on the sites are selected.

C.4.3.5 Impact Assessment Methods for Water Resources

The environmental impacts on surface water and groundwater availability and groundwater quality were assessed by determining the potential change from baseline conditions caused by implementing the Alternatives. A summary of the water resources impacts that were evaluated in detail in the PEIS is shown in Table C.4–13.

First, current conditions at the sites were summarized from data in the *Technical Report on Affected Environment* (DOE, 1995b). Table C.4–14 shows the affected environment information used for each site, which includes the following types of information:

- Source(s) of water for the site
- Current rate of municipal water use (gallons per day)
- Current rate of surface water use (gallons per day)
- Current rate of groundwater use (gallons per day)
- Location of wastewater discharge(s)
- Average streamflow for the major water body (gallons per day)
- The presence of Sole-Source Aquifers in the ROI as defined by the EPA
- The presence of Federally designated Wild and Scenic Rivers in the ROI

Then the applicable facility design data for the sites affected by the proposed alternatives were assembled from the data tables in this appendix, including:

- Water used during construction (total gallons)
- Water used during operations (gallons per year)

Water used during construction was converted to daily usage by dividing by the total number of days of the construction period, assuming 250 work days per year and a 2-year construction period. Water used during operations was converted to daily usage, assuming 250 work days per year. Figures for the number of work days per year for construction and operation and for the duration of the construction period were supplied in the EG&G reports (e.g., EG&G and MK, 1994).

Table C.4–13. Impacts Evaluated in Detail for Water Resources

Impacts Assessed	Relevant Waste Types	Period of Analysis	Activities for Which Impacts Are Assessed	Impacts Measure	Presentation of Results
Water Availability	All five waste types	Construction	Estimated for water used: – by personnel – for concrete – for dust suppression	Percent increase in current water use	Tabular and text discussion
				Percent decrease in stream flow	Text discussion
	All five waste types	Operations	Estimated for water used: – by personnel – by treatment and disposal processes	Percent increase in current water use	Tabular and text discussion
				Percent decrease in stream flow	Text discussion
			Estimated for effluent discharged from sanitary and process wastewater treatment facilities	Percent increase in stream flow	Text discussion
Groundwater Quality	LLMW and LLW	Post-Closure	Disposal of waste	Percent of drinking water quality standard	Tabular and text discussion

The following calculations were performed for each alternative by combining the baseline environmental data with the facility design data:

- Percentage of current site water usage for increment added during construction
- Percentage of average streamflow for water usage increment added during construction
- Percentage of current site water usage for increment added during operations
- Percentage of average streamflow for water usage increment added during operations
- Percentage of average streamflow for effluent discharge increment added during operations, assuming that all water used is ultimately discharged as effluent from a wastewater treatment facility

These calculations formed the basis for assessing the impacts of the proposed alternatives on water availability.

Table C.4–14. Affected Environment Data for Water Resources[a]

Site	Source of Water Supply for Site	Current Use (gpd)			Waste-Water Discharge Location	Average Flow in Major Stream (gpd)
		Municipal Water	Surface Water	Groundwater		
ANL-E	Chicago Sanitary & Ship Canal and Niagara Aquifer	NA	350,000	626,000	County of DuPage Municipal Sewer System, Sawmill Creek	582,000,000
BNL	Upper Glacial Aquifer & Magothy Aquifer[b]	NA	NA	4,500,000	Onsite Streams & Peconic River	1,000,000
FEMP	Miami Valley Aquifer[b]	NA	NA	400,000	Onsite Streams & Great Miami River	1,823,000,000
Hanford	Columbia River, Deep Wells and City of Richland Municipal System	d	9,567,000	184,000	Onsite Drain Fields, Evaporation Ponds & Columbia River	77,560,000,000
INEL	Snake River Plain Aquifer[b]	NA	NA	5,700,000	Onsite Evaporation Ponds	NA
LANL	Main Aquifer	NA	NA	4,100,000	Onsite Canyons	1,727,000,000
LLNL Site-300	Deep Groundwater & Hetch Hetchy Aqueduct	e	NA	87,000	Onsite Ponds and Leach Fields	NA
LLNL-L	Hetch Hetchy Aqueduct and Alameda County	717,000	NA	NA	City of Livermore Municipal Sewer System	NA
NTS	Groundwater	NA	NA	1,367,000	Onsite Evaporation Ponds	NA
ORR	Clinch River	NA	18,300,000	NA	Onsite Streams & Clinch River	3,003,000,000
PGDP	Ohio River	NA	15,000,000	NA	Onsite Streams & Ohio River	174,521,000,000
Pantex	Ogallala Aquifer	NA	NA	548,000	Onsite Playas	NA
PORTS	Alluvial Aquifer & Scioto River	NA	0	14,000,000	Onsite Streams & Scioto River	3,036,000,000
RFETS	Denver Water Board	272,000	NA	NA	Onsite Streams & Walnut Creek	142,000,000
SNL/NM	City of Albuquerque & Kirtland Air Force Base	1,000,000	NA	NA	City of Albuquerque WWTP	651,000,000
SRS	Groundwater & Savannah River	NA	112,000,000	1,600,000	Onsite Streams & Savannah River	6,463,000,000
WIPP	City of Carlsbad Municipal System	14,400	NA	NA	Onsite Evaporation Ponds	NA
WVDP[c]	Two Onsite Surface Water Reservoirs	NA	70,000	NA	Onsite Streams & Buttermilk Creek	41,000,000

Notes: WWTP = waste water treatment plant. NA = not applicable. INEL includes INEL, ANL-W, and NRF. LLNL-L includes LLNL-L and SNL/CA. SNL/NM includes SNL/NM and ITRI.

[a] Data from the *Technical Report on Affected Environment for DOE Sites Considered in the Waste Management Programmatic Environmental Impact Statement* (DOE, 1995b). No Sites have Federally designated Wild and Scenic Rivers in the ROI, although the Hanford Reach of the Columbia River was recommended for inclusion (DOI, 1994).

[b] Sole-source aquifer.

[c] Site is upstream from a sole-source aquifer.

[d] Water use rate not available. Municipal water used to supply administrative areas (700, 1100, and 3000 Areas) near the City of Richland only.

[e] New system that has a capacity of 500,000 gallons/day.

Percentages less than or equal to 1% were considered to be negligible and were not discussed further. The 1% threshold is based on the assumption that a change in current conditions of this magnitude is not likely to produce a significant impact. Thus the 1% level was used as a screening level below which impacts were assumed to be minor.

Percentages greater than 1% were examined on a case-by-case basis because impacts would depend on the characteristics of the affected site. At one site a change in groundwater usage of 10% may be problematic, while at another site a change of this magnitude may not be a problem. When necessary, water usage was compared to the capacity of the water supply distribution system, regional water use, or water rights agreements to determine if these values would be exceeded. The effects of projected demands for proposed facilities on existing water supply or wastewater treatment infrastructures are evaluated in the section on infrastructure impacts.

The impacts of waste disposal on groundwater quality were estimated by using the information for the groundwater pathway generated during the health effects modeling. The movement of contaminants was modeled for each site using the Multimedia Environmental Pollutant Assessment System (MEPAS) code, modified to better account for radioactive decay and ingrowth of daughter radionuclides. The model estimated concentrations for radionuclides and hazardous constituents at a hypothetical well located 300 meters from the center of the disposal facility for 70-year increments between the end of institutional control and 10,000 years. Impacts from leakage during operations and institutional control are unlikely since leachate and groundwater monitoring are likely to detect the leak before significant degradation of groundwater quality could occur. Disposal of 36 radionuclides was evaluated for LLMW and LLW; disposal of 15 hazardous constituents was evaluated for LLMW. The maximum concentrations above 0.001 pCi/L for radionuclides and 0.000001 mg/L for hazardous constituents were then tabulated and compared to groundwater quality comparison criteria. The year of the maximum concentration was also included in the tabulation. Values above 25% of the comparison criteria were noted, and the potential impacts of these concentrations were discussed in the PEIS. Appendix D provides more detail on the health effects methodology used to model the groundwater pathway. This appendix states that the uncertainty in the health risk results for the groundwater pathway is approximately one or two orders of magnitude.

As shown in Table C.4–15, water quality comparison criteria used in the PEIS include maximum contaminant levels of the EPA National Primary Drinking Water Regulations (40 CFR 141) and standards for drinking water from DOE Order 5400.5 (DOE, 1990). Drinking water standards promulgated under the SDWA are applicable to treated drinking water at the tap and therefore do not directly apply to

Table C.4–15. Water Quality Comparison Criteria

Constituent	EPA Drinking Water Regulations			DOE Derived Concentration Guides for Drinking Water[d]	EPA Quality Criteria for Fresh Water[e]	
	MCL[a]	SMCL[b]	Proposed MCL[c]		Acute	Chronic
1,2-Dichloroethane	0.005				118	20
Actinium-227			1.27	0.4		
Americium-241			6.34	1.2		
Americium-242m			1.27	1.2		
Americium-243			6.37	1.2		
Arsenic	0.05				0.36	0.19
Barium	1					
Benzene	0.005				5.3	
Cadmium	0.005				0.0039	0.0011
Carbon Tetrachloride	0.005				35.2	
Carbon-14			3,200	2,800		
Cesium-135			794	800		
Cesium-137			119	120		
Chromium +VI	0.1				0.016	0.011
Curium-242			133	40		
Curium-244			9.84	2.4		
Curium-245			6.23	1.2		
Cyanide	0.2				0.022	0.0052
Iodine-129			21	20		
Lead	0.015[f]				0.082	0.0032
Mercury	0.002				0.0024	0.000012
Methylene Chloride	0.005					
Neptunium-237			7.06	1.2		
Nickel-59			27,000	28,000		
Nickel-63			9,910	12,000		
Palladium-107			36,600	40,000		
Plutonium-238			7.02	1.6		
Plutonium-239			62.1	1.2		
Plutonium-240			62.2	1.2		
Plutonium-241			62.6	80		
Potassium-40				280		
Protactinium-231			10.2	0.4		
Radium-226	3[f]		20	4		
Samarium-151			14,100	16,000		
Selenium	0.05				0.26	0.035
Selenium-79				800		
Silver		0.1			0.0041	0.00012
Strontium-90	8		42	40		
Technetium-99			3,790	4,000		
Thorium-229			49.3	1.6		
Thorium-230			79.2	12		
Thorium-232			88	2		

Table C.4-15. Water Quality Comparison Criteria—Continued

Constituent	EPA Drinking Water Regulations			DOE Derived Concentration Guides for Drinking Water[d]	EPA Quality Criteria for Fresh Water[e]	
	MCL[a]	SMCL[b]	Proposed MCL[c]		Acute	Chronic
Tin-126 (mg/L)			293	320		
Uranium-233 (pCi/L)			13.8	20		
Uranium-234 (pCi/L)			13.9	20		
Uranium-235 (pCi/L)			14.5	24		
Uranium-236 (pCi/L)			14.7	20		
Uranium-238 (pCi/L)			14.6	24		
Zirconium-93 (mg/L)			5,090	3,600		

Note: Blank cells indicate that no official standard or criterion exists for this constituent. MCL = maximum contaminant level. SMCL = secondary maximum contaminant level. Comparison criteria for 1,2,2-trichloro-1,1-trifluoroethane and acetone were not found.
[a] Source: 40 CFR 141, *National Primary Drinking Water Regulations*, and EPA (1991a).
[b] Source: 40 CFR 143, *National Secondary Drinking Water Regulations*. SMCLs based on taste and odor effects.
[c] Source: EPA (1991a). Concentration based on 4 mrem/year dose. Alpha emitters based on lifetime incidence risk of 1×10^{-4}.
[d] Source: DOE Order 5400.5 (DOE, 1990). Concentration based on 4 mrem/year effective dose equivalent.
[e] Source: EPA (1986).
[f] Action level.

groundwater quality. Since there are no Federal standards for groundwater quality protection, predicted concentrations of contaminants in the groundwater are compared with drinking water standards to indicate the level at which adverse impacts to water quality may occur. These criteria are commonly used as Applicable or Relevant and Appropriate Requirements (ARARs) to determine appropriate levels for groundwater cleanup under RCRA and CERCLA cleanup actions. Since drinking water standards adequately protect human health, groundwater contamination at or below these levels is considered to result in low risk to human health. EPA National Secondary Drinking Water Regulation secondary maximum contaminant levels (40 CFR 143) were used as comparison criteria where maximum contaminant levels did not exist, although they focus on qualities of taste and odor rather than protection of health.

The EPA proposed maximum contaminant levels for radionuclides in drinking water (EPA, 1991a) were not used because they are proposed regulations that are not yet in effect. Note that most of the EPA proposed drinking water standards for radionuclides are similar to the DOE derived concentration guides that were used. EPA quality criteria for fresh water (EPA, 1986) were not used since these apply primarily to surface water quality.

Federal water quality standards were used to provide a consistent means of comparison among sites. Using State water quality standards could bias the analysis toward sites with less stringent environmental laws.

This would be unfortunate since impacts occur in relation to the amount of contamination present. Impacts do not necessarily parallel regulation of the contamination.

It is important to note that DOE Order 5820.2A (DOE, 1988) for radioactive waste management, RCRA for hazardous waste, the Toxic Substances Control Act for waste containing PCBs, and DOE's Performance Assessment process would not allow a disposal facility to be constructed that would cause significant contamination of groundwater outside the facility boundary. If significant groundwater contamination was predicted by the Performance Assessment process, changes in the waste acceptance criteria would be made to limit disposal of the waste causing the problem. The wastes would require additional treatment prior to disposal, would be disposed at another DOE site where the wastes meet the waste acceptance criteria, or would be stored until a method was found to treat or dispose of the waste. In no case would DOE knowingly dispose of waste in violation of legal requirements.

Indirect impacts to water resources were deferred to site-specific or project-level NEPA documents. These include the effects of increased offsite water use caused by in-migrating employees and their families.

C.4.4 Ecological Impacts Analysis Methods

Effects on ecological resources of waste treatment, storage, or disposal activities proposed at the 17 major DOE sites and the impacts of waste transportation were evaluated for each waste type under each alternative for:

- Routine activities of constructing and operating WM facilities
- Accidental releases of transported wastes

Table C.4–16 lists the ecological impact type, the particular resources affected, the general method used, the waste types to which each method was applied, and the type of presentation format for each ecological impact evaluated.

C.4.4.1 Routine WM Activity Impacts

The ecological impacts of routine WM activities were assessed in terms of potential disturbance or loss of nonsensitive terrestrial habitat resulting from site clearing for construction of WM facilities, the potential

Table C.4-16. Ecological Resources Impacts Analyzed for the WM Alternatives

Ecological Impact Analyzed	Affected Ecological Resource	Impact Analysis Method	Applicable Waste Types	Presentation of Results
Habitat Effects—Routine WM Activities				
Nonsensitive Habitat Loss	Terrestrial plants and animals	Comparison of habitat loss at WM construction sites to general habitat range	All five types	Text discussion
Potential for Sensitive Habitat Effects	Nearby wetlands and other sensitive habitats	Likelihood of impacts to nearby sensitive habitats by comparing construction acreage to available acreage of nonsensitive habitats	All five types	Text discussion
Contaminant Exposures—Routine WM Activities				
Terrestrial Species Exposures	Terrestrial animal species	Comparison of estimated radiation dose of representative species with toxicity standard	LLMW, LLW, TRUW	Text discussion
Habitat Effects or Contaminant Exposures—Routine WM Activities				
Sensitive Species Concerns	Federally and State-listed endangered and threatened species	Numbers of Federally and State-listed species displayed by site/alternative	All five types	Tabular listing
Contaminant Exposures—Accidents				
Effects of Transportation Accidents	Aquatic Species in Streams crossing transportation corridors	Results of scenario-based modeling analysis of accidental spill effects on fish in various size streams	LLMW, LLW, TRUW	Text discussion

for site clearing and WM facility operations to affect nearby sensitive habitats, and the potential for airborne contaminant releases from waste treatment facilities to be toxic to terrestrial wildlife.

C.4.4.1.1 *Direct Nonsensitive Habitat Impacts*

During the construction phase, ecological resources will be affected through disturbance or loss of habitat resulting from site clearing. Terrestrial resources will be directly affected by land clearing through changes in vegetative cover, which will adversely affect the habitat of terrestrial animals.

These changes may be important for individual animals of certain species with limited home ranges, such as small mammals and songbirds. Likely impacts include increased direct mortality and susceptibility to predation. Individual animals with larger home ranges, such as game animals and raptors, may not be adversely affected by the decreases in vegetative cover resulting from site construction. In general, it is not expected that any nonsensitive species populations will be affected by the limited amounts of nonsensitive habitats lost or disturbed in the WM program. The discussion of the potential for these effects in the waste-type chapters draws a comparison between the limited amounts of acreage likely to be disturbed in managing the waste type at individual sites and the extent of the nonsensitive habitats available regionally.

C.4.4.1.2 *Indirect Sensitive Habitat Impacts*

Many of the DOE sites contain sensitive habitats. The degree to which those habitats would be unaffected by noise or vibration disturbance, human presence, vehicle or equipment emissions, runoff, or encroachment by nearby WM facility construction or operations activities at any site would depend on DOE's ability to avoid locating the facilities near the sensitive habitats. A measure of this ability is the percentage of available land that facility construction under any WM alternative would require at a site. Available acreage was estimated from site development plans either using land designated for waste operations or subtracting the acreage of existing structures and sensitive habitats, such as wetlands and wildlife management areas, from the total site acreage. Potential for impacts was assessed by estimating the percentage of available land by site and alternative and listing those that equal or exceed 1% in the waste-type chapters. Further evaluation of those sites where the percentage equals or exceeds 1% is presented in the waste-type chapters in terms of the expectation that DOE will be able to avoid impacts to sensitive habitats.

Aquatic resources may be indirectly affected through increased runoff and sedimentation loadings to surface waters from disturbed terrestrial areas. However, the use of various mitigation techniques should minimize potential facility construction impacts to aquatic ecological resources. Direct discharges of contaminants to surface waters from the routine operation of facilities are expected to be limited by engineering control practices. Therefore, impacts to aquatic organisms are expected to be minimal.

Habitat Effects Data Sources. Estimates of the acreage cleared to build WM facilities were compiled from the engineering analysis outputs described in Section C.3 of this appendix. For each waste type and WM

alternative, the total disturbed area was estimated by summing the plant area required for all WM facility modules (plus 25-foot buffer zones) and the parking area. Plant area was estimated as a function of waste throughput requirements, whereas, parking area was estimated on the approximate number of full-time plant employees. Available acreage was estimated using site development plans and site environmental reports.

Habitat Effects Data Evaluation. For nonsensitive habitat impacts, the construction acreage requirements at each site under each alternative are compared qualitatively with the general extent of these habitats in the affected regions.

For sensitive habitat impact evaluation, sites where the proposed construction activities would disturb more than 1% of the available WM area are noted in the waste-type chapters and additional discussion is included about whether these greater percentages would indicate that indirect effects to sensitive habitats are likely. Additional investigations of the type that would be conducted as part of the site-specific or project-level NEPA evaluations tiered to the PEIS, would be needed to confirm or refute any presumed significant habitat impacts.

C.4.4.1.3 *Potential Toxicity to Terrestrial Wildlife*

The impacts of airborne releases of radionuclides and hazardous chemicals to terrestrial animals living near waste treatment facilities were estimated using atmospheric emission/deposition modeling. This modeling, which used the same atmospheric emissions estimates as used in the human health risk assessment, provided estimates of doses of radiological and nonradiological contaminants deposited onto near-field and far-field surface soils. The model also estimated uptake from the soils and transfer in a terrestrial food chain leading to exposure of a small mammal used as a model terrestrial receptor.

The white-footed mouse (*Peromyscus leucopus*) was used in this analysis to be representative of most small mammals because it is sensitive to contaminant exposure, it has a varied diet (for example, it eats both plants and insects), and it is a common prey species for a number of predators. In addition, field mice are ubiquitously distributed. These animals have a limited home range relative to estimated contaminant distributions. Therefore, mice live within potentially contaminated areas and can be expected to consume all of their diet from these areas.

C.4.4.1.3.1 Data Sources

Contaminant toxicity evaluations were conducted using the same estimates of waste treatment facility airborne emissions as were used in the human health risk analyses. These annual emission rate estimates, provided by ANL, were assumed to be constant over a 10-year operating period. Contaminants that accounted for up to 80% of total emissions were included in the assessment; trace emissions were not assessed.

Emission estimates were used as inputs to atmospheric dispersion/deposition models, which provided estimates of contaminant concentrations deposited to surface soils. Surface soil contaminants were then modeled for distribution in terrestrial food chains using a number of transfer factors.

Estimates of maximum near-field and far-field contaminant concentrations were developed in order to conservatively assess exposure. The pathways used to estimate internal and external exposure include direct exposure to external radiation, incidental soil ingestion, and uptake of contaminants from soils into terrestrial food chains. Exposure from the inhalation and water ingestion pathways was assumed to be minimal due to dilution.

Surface soil concentration estimates were developed for each contaminant by applying the maximum near-field and far-field deposition rates to the contaminant emission rates. Except for tritium, contaminants were conservatively assumed to accumulate in the soil over the 10-year operation period. Radioactive decay was accounted for in the analysis. Contaminants were assumed to be evenly distributed in the top six inches of soil.

Terrestrial food chain contaminant concentration estimates were made by applying transfer factors to soil concentrations to develop concentration estimates in plant tissues. Since reliable transfer factors were not available for estimating concentrations in insect tissue from plant tissue concentrations, complete (100%) plant to invertebrate transfer was conservatively assumed to estimate invertebrate tissue concentrations (ORNL, 1995b).

Tritium exposure was assessed separately. Tritiated water is the principal form of tritium in the environment. Therefore, tritium can be expected to be incorporated into a great variety of compounds but cannot be assumed to accumulate in soils. For tritium, a simplifying assumption was made that tritium

deposition is continuous and uniform over time and that tritium in the receptor mouse has attained a steady state equilibrium with environmental tritium (IAEA, 1992). Transfer factors for tritium were conservatively assumed to be 100% (ORNL, 1995b).

C.4.4.1.3.2 Data Evaluation

The potential toxicity of the radiological contaminants was assessed by comparing the estimated total internal and external doses to a benchmark value of 100 mrad/day, established by the International Atomic Energy Agency (IAEA, 1992). No-observable-adverse-effect levels (NOAELs) were used as benchmarks for the nonradiological (i.e., hazardous chemical) contaminants. The radionuclides selected for each analysis comprised 80% of the total volume of all radionuclides expected to be emitted at a given site. The radionuclides were used in calculating hazard indexes (HIs) for each selected site/alternative combination as composite ratios between the estimated species exposures to each of the contaminants and known, contaminant-specific toxic levels. The resulting ratio, the HI, was used to identify WM alternatives that may be of concern for potential ecotoxicity. An HI greater than one would indicate a potential for the combined exposures to adversely affect the health of terrestrial species. Hazardous and toxic chemicals were evaluated using a separate HI in the same way.

C.4.4.1.4 *Potential Impacts to Sensitive Species*

Location-specific analyses would be required to address impacts to sensitive habitats and sensitive species, including species listed by the U.S. Fish and Wildlife Service as endangered or threatened. Those analyses would be part of the impacts analyses in NEPA documents tiered to this PEIS. For comparison of WM program effects on sensitive species, the waste-type chapters list the numbers of Federal and State-listed endangered and threatened species at each site under each alternative where a major action is proposed. Reference is made to the PEIS Chapter 4, Affected Environment, which lists the sensitive species at the 17 major sites.

C.4.4.2 Impacts of Accidental Releases

The ecological impacts of waste transportation accidents were evaluated as consequence assessments of spills into aquatic environments. These assessments estimated the potential ecological impacts of transportation accidents involving varying size releases of radionuclides under certain spill scenarios. However, they do not include estimates of the probability of these events occurring.

Because hazardous constituents would vary so widely in volume and type in any particular mixed or hazardous waste shipment, no attempt was made to quantify the consequences of hazardous constituents in transportation accidents. Where applicable, the PEIS acknowledges that the consequences of those spills may be as severe or more severe than the consequences of spills of radioactive wastes.

Accidental spills in nonsensitive terrestrial environments were not quantified but are expected to have more limited consequences than those estimated for the aquatic scenarios because the extent of the affected area would be more limited to the immediate locality of the spill and cleanup would likely be more effective because of the stable nature of the affected substrate. Airborne contaminants released downwind through such accidents could affect terrestrial species through all routes of exposure. The effects of such releases on nearby exposed humans were evaluated and are presented in the PEIS waste-type chapters and the human health risk appendix (Appendix D). Terrestrial species would be at similar levels of risk for any acute effects.

Facility accidents would also likely affect terrestrial and aquatic environments on and near the affected site. Such accidents were evaluated for effects on human health. Ecological impacts are likely to be as severe as those shown in the human health effects analysis, however, no separate quantitative analysis of ecological impacts was done.

The transportation accident scenario used involves a rail shipment spill of waste directly into surface waters of different size classes. Assessments were performed for stream size classes ranging from a small second order stream (for example, flow rate of a few meters per second) to a tenth order major continental river (for example, the Mississippi River). Stream order is a method of numbering steams as part of a drainage basin network. The smallest tributary is called first order, the stream receiving the tributary is called second order, and so on. There are about 350,000 second-order streams in the United States and only one tenth-order stream, the Mississippi River.

The environmental fate of the spilled waste was evaluated under two assumptions. In one case, it was assumed that all spilled material remained suspended or dissolved in the water column and was transported downstream. Aquatic organisms present at any given location were assumed to be exposed for a maximum of four days to the maximum concentration of waste material. Contaminant concentrations would be reduced by longitudinal dispersion as the contaminants move downstream. Biota in the water column would receive an external exposure to suspended or dissolved radioisotopes.

In the other case, it was assumed that all of the released material was immediately deposited on the stream sediment at the release site. Aquatic organisms present at the release site were assumed to be exposed over their entire lifetime. Benthic (that is, bottom dwelling) biota would receive an external exposure from radiological waste deposited in sediment. If the deposited materials were allowed to remain in the sediment for a sufficient length of time, many isotopes would become incorporated into aquatic food chains. Food chain exposure would produce internal exposures for benthic organisms and for fish or other organisms that feed on them.

C.4.4.2.1 *Data Sources*

Estimates of the potential impacts of transportation accidents to aquatic organisms were conducted by Oak Ridge National Laboratory (ORNL, 1995b). ORNL used the waste load source term data provided by ANL as inputs to aquatic environmental fate models to estimate maximum credible radiological releases for transportation accidents involving HLW, LLW, and CH and RH TRUW. For each waste type, ANL provided information on the radionuclides and total activity present in a shipment and on the total release in a maximum severity accident. ANL concluded that for HLW and TRUW only a small portion of the total shipment inventory would be released because the only credible accidental release mechanisms for these waste types involve small cracks and seal failures in shipping containers. The entire contents of the LLW shipment were assumed to be released during a maximum severity accident; however, only a small fraction of the release was assumed to be soluble. The analysis of LLMW was based on the LLW results. Effects for HW and the chemical component of LLMW were not quantified as noted above (ANL, 1996a).

The source terms used in the assessment were obtained by screening the source terms from all sites for all alternatives for these waste types to identify the waste shipments that would result in the highest releases.

The environmental fate of the spilled contaminants was estimated using a two-dimensional aquatic chemical fate model (EPA, 1985c). It was assumed that all of the spilled material remained in the water column for transport downstream or to sediment (ORNL, 1995b).

C.4.4.2.2 *Data Evaluation*

For aquatic biota, adverse short-term effects (that is, acute toxicity) are assumed to occur if the estimated doses exceeded the maximum safe dose of one rad per day (rad/day) recommended by the National Council on Radiation Protection and Measurements (NCRP, 1991). The results of the water column assessment include estimates of (1) the length (meters) of the stream (for each size class) affected before longitudinal dispersion reduces the exposure below the NCRP threshold; and (2) the time (hours) required for this dispersion to occur.

The results of the sediment assessment include estimates of the amount (kilogram) of clean sediment needed to dilute the spilled material to a sediment activity level corresponding to a one rad/day lifetime dose to a large fish residing at the bottom of the stream and feeding on benthic biota. This value also should be a reasonable estimate of the amount of sediment that would have to be removed during a remedial action taken following the spill.

C.4.5 Economic Impacts Analysis Methods

The economic impact analysis methods were used to estimate the economic impacts of the WM alternatives on the regional and National economies. The impacts assessment addressed potential changes in regional employment, personal income, and industry output due to WM expenditures at the 17 major sites (Table C.4–17). The assessment also addressed changes in National employment, personal income, and industry output due to the sum of spending on WM facility activities at all applicable sites and on waste transportation between sites under each waste type alternative. This section describes the analysis procedures, assumptions, data, evaluation techniques, and the presentation of the results from the economic impacts analysis.

Table C.4-17. Economic Impacts Analyzed for the WM Alternatives

Economic Impact Analyzed	Affected Aspect of Economy	Impact Analysis Method	Presentation of Results
Effect on regional employment	Level of regional employment at the major sites	Proposed site expenditures multiplied by regional employment multiplier at each major site	Tabular or text-only depending on range of results
Effect on regional incomes	Level of regional personal income at the major sites	Proposed site expenditures multiplied by regional income multiplier at each major site	Tabular or text-only depending on range of results
Effect on regional industry output	Value of regional industrial production	Proposed site expenditures multiplied by regional income multiplier at each major site	Presented in Environmental Impacts Technical Report only
National economic effects	National employment, personal income, and industry output	Proposed site expenditures at all involved sites plus intersite transportation costs multiplied by national employment, income, and industry output multipliers	Text discussion

C.4.5.1 Focus of the Economic Impact Assessment

The economic impact analyses of the WM alternatives used a methodology that is standard for industrial construction projects, although the WM program presents several unique economic considerations because the WM facilities are designed to treat, store, and/or dispose of radioactive and hazardous waste. Because processing of these wastes requires substantial provisions to decrease the probability of harm to human health and the environment, special costs apply that include the costs of environmental documentation, for example, under Resource Conservation and Recovery Act (42 USC 6901 *et seq.*) and NEPA (42 USC 4321 *et seq.*), for monitoring, and for shielding.

The specific project expenditure categories include design and planning, testing, construction, cold start, O&M, D&D, and transportation. These expenditures and their respective time periods are not uniform across waste types. For example, there is no D&D phase for high-level waste. In the case of the alternatives for hazardous waste, there are expenditures proposed for commercial treatment, storage, and disposal facilities that factor into the National economy. Expenditures were aggregated into three major phases: construction, operations, and transportation. The construction phase encompasses all activities from the design phase through the cold start. The operations phase encompasses the O&M period as well as D&D. The transportation phase generally coincided with the O&M portion of the operations phase. The analysis

focused on the economic consequences of spending money on waste management activities within these major project phases. The full economic consequences of waste management activities were assumed to continue for an additional five years beyond the end of each phase (Cuthbertson and Nitzsche, 1994).

DOE recognizes the potential for economic effect on the ROI resulting from negative perceptions associated with its waste management program; for example, real estate property values in the vicinity of a radioactive waste disposal facility may decline, or the ability of the region to attract a diversified business base may be affected. However, although these potential impacts are recognized, they are not amenable to analysis at the programmatic level and in the absence of a specific location for the facility proposed. The nature and extent of such impacts is therefore not included in this PEIS.

C.4.5.2 Quantitative Effects

The principal variables selected to characterize the regional and National economics and provide the baseline conditions for the 17 major sites—employment, per capita income, and population—are presented in Chapter 4. Per capita income was multiplied by population to calculate total personal income. Data for these variables are provided for 1990 in 1990 dollars.

The economic analysis employed three standard measures of change—employment, personal income, and industry output—as indicators of the potential impact of the WM alternatives. Changes in these indicators form the basis for the comparison of alternatives. Results of the analysis are presented both as absolute numbers and as changes over the 1990 baseline for the ROI as a whole. Since the absolute numbers are used, alternatives can be compared with each other in terms of absolute overall effect, independent of other, external changes in the prevailing conditions of the region of influence.

By comparing values for these indicators with the No Action and Decentralized Alternatives at a given site, the effect, in terms of a net change (either decrease or increase), can be determined for each of the other alternatives (see site tables, volume II). In addition to providing data on potential increases in these variables, the analysis also provides a basis for assessing the potential for losses in employment due to the shifting of work away from the site. This is available in the existing analysis as a comparison of the effects presented for the Decentralized or No Action Alternatives with the remaining alternatives.

The economic impact analysis estimated changes in employment, personal income, and industry output that would result from the direct infusion of project dollars into the regional and national economies and subsequent multiple cycles of spending. The following definitions of these variables apply to both the affected environment and impact chapters of the PEIS.

C.4.5.2.1 *Employment*

One of the variables that the economic impacts generated by the model described below is "job-years." The variable "job-years" is equivalent to person-years, or full-time equivalents. One job-year is equal to 2,080 hours of employment in a twelve month period. Employment is the count of full- and part-time jobs. Job-years is converted to jobs or employment by dividing the number of job-years by the number of years over which the initial expenditures take place, plus the additional time it takes for the successive rounds of expenditure to occur (i.e., five years for each phase).

Employment impacts are presented according to place of work. Employment by place of work shows how many people work in a given region irrespective of where they live. The workforce of a regional economy is considered to be the number of people that work in a given region (as opposed to the number of people that live and work in the region). The economic impact analysis is geared to determine what the change in direct, indirect, and induced employment would be given a change in expenditures in the region. The research question is one of how many jobs will be generated in total, not how many jobs will be generated for the people that live in a given county.

The employment by place of residence shows how many people in a given region (a county or aggregation of counties) have jobs, irrespective of which region their jobs are in. The affected environment chapter in the PEIS (Chapter 4) provides employment by place of residence for the 17 major DOE sites. The ratio of the site workforce to employment by place of residence is an indicator of regional economic dependence on DOE sites. If there were a change in the number of jobs at a site, the change in the unemployment rate would be reported by where people live, not work.

While the data will indicate the direction of change, information on the magnitude of the changes will be more vague. It will be difficult to gauge the change in the unemployment rates due to a change in waste management spending, for example, but estimates of the magnitude of change in employment can be given. The percentage of earnings to labor from each of the "division level" Standard Industrial Classification

(SIC) codes gives a useful snapshot of the character of the economy, but it will not be possible to determine how the composition of labor earnings will change given the implementation of one of the alternatives at a site. This is because the programmatic level of analysis must focus on a level of detail that enables a comparison of alternatives across sites and waste types. Analyzing changes in the composition of earnings obscures the importance of variables that facilitate a meaningful comparison of alternatives.

Baseline employment (by place of work) and baseline personal income for every ROI has been extracted from the U.S. Bureau of Economic Analysis' Regional Economic Information System (DOC, 1992a) and is presented in Tables C.4–18 and C.4–19.

C.4.5.2.2 *Personal Income*

Total personal income is defined as pre-tax disposable income to the household sector. It is useful as a measure of the purchasing power available to consumers. The impacts analysis uses a measure of income that subtracts taxes out of the first cycle of spending. While the two measures are not identically defined, the numbers are similar enough that they can be combined.

C.4.5.2.3 *Industry Output*

Output is defined as gross industry receipts (DOC, 1992b), i.e., the number of units of goods and services that are sold times the price per unit. Output is useful in illustrating the magnitude of economic activity in a given region or in the national economy. Output, however, has two important limitations:

- Output includes the revenues for each cycle of expenditure. Therefore, the value of a given good or service may be accumulated several times as an intermediate good before it is ultimately sold as a final good to the consumer.
- Baseline measures of output are not available at the regional level. The model used to determine impacts provides a change in output given a change in initial expenditures, but data are not available to compute a percent change in the baseline output.

Table C.4–18. Baseline Employment Data

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
Ames	Boone (IA)	10,266	11,351	11,684	11,006	11,205	9.1%
	Hamilton (IA)	8,237	8,969	9,427	9,418	10,210	24.0%
	Hardin (IA)	10,110	10,809	11,822	11,290	11,323	12.0%
	Jasper (IA)	15,997	16,390	16,889	16,770	17,823	11.4%
	Marshall (IA)	20,632	22,377	23,519	21,779	23,065	11.8%
	Polk (IA)	157,758	179,201	206,377	216,637	255,686	62.1%
	Story (IA)	28,296	33,610	40,419	42,245	46,365	63.9%
		251,296	282,707	320,137	329,145	375,677	49.5%
ANL-E	Cook (IL)	2,780,014	2,742,358	2,873,797	2,885,969	3,080,458	10.8%
	Du Page (IL)	154,520	215,484	282,623	382,481	510,994	230.7%
	Kane (IL)	108,159	117,301	131,252	141,234	171,116	58.2%
	Will (IL)	87,178	90,369	100,401	104,134	121,273	39.1%
		3,129,871	3,165,512	3,388,073	3,513,818	3,883,841	24.1%
BCL	Delaware (OH)	15,851	17,914	21,449	23,432	27,026	70.5%
	Fairfield (OH)	27,211	30,877	36,655	35,308	38,948	43.1%
	Franklin (OH)	399,431	447,635	512,397	576,164	680,737	70.4%
	Licking (OH)	41,660	43,642	50,269	52,119	56,828	36.4%
	Madison (OH)	9,124	9,763	10,205	10,262	13,287	45.6%
	Pickaway (OH)	14,546	16,037	17,188	16,031	17,800	22.4%
	Union (OH)	10,672	11,289	12,486	15,042	22,671	112.4%
		518,495	577,157	660,649	728,358	857,297	65.3%
Bettis	Allegheny (PA)	730,822	731,255	765,235	742,910	802,173	9.8%
	Armstrong (PA)	22,139	24,075	24,607	23,111	24,280	9.7%
	Beaver (PA)	81,428	87,386	86,106	64,258	62,093	-23.7%
	Butler (PA)	46,384	49,600	56,201	56,647	67,382	45.3%
	Washington (PA)	71,399	77,275	79,039	73,958	80,823	13.2%
	Westmoreland (PA)	123,374	131,997	147,434	141,501	151,582	22.9%
		1,075,546	1,101,588	1,158,622	1,102,385	1,188,333	10.5%
BNL	Nassau (NY)	556,601	581,113	648,039	749,839	771,414	38.6%
	Suffolk (NY)	317,836	378,992	470,017	586,728	647,626	103.8%
		874,437	960,105	1,118,056	1,336,567	1,419,040	62.3%
Charleston	Berkeley (SC)	12,091	15,250	23,617	27,331	33,869	180.1%
	Charleston (SC)	130,125	147,319	167,296	196,497	226,839	74.3%
	Colleton (SC)	10,507	10,942	11,591	12,568	13,805	31.4%
	Dorchester (SC)	8,701	11,782	15,983	21,662	25,392	191.8%
		161,424	185,293	218,487	258,058	299,905	85.8%
Colonie	Albany (NY)	179,332	183,478	203,657	225,005	256,215	42.9%
	Columbia (NY)	17,950	19,455	20,598	22,942	25,561	42.4%
	Greene (NY)	11,675	13,144	14,306	15,456	17,034	45.9%
	Rensselaer (NY)	44,314	44,726	46,767	52,406	61,152	38.0%
	Saratoga (NY)	30,254	35,894	44,418	54,378	68,058	125.0%
	Schenectady (NY)	71,461	75,442	75,567	75,564	79,628	11.4%
	Schoharie (NY)	7,799	8,514	8,656	9,267	10,655	36.6%
		362,785	380,653	413,969	455,018	518,303	42.9%
ETEC	Kern (CA)	136,096	166,838	198,411	231,191	259,475	90.7%
	Los Angeles (CA)	3,326,115	3,551,891	4,272,799	4,661,161	5,199,569	56.3%
	San Luis Obispo (CA)	37,913	48,874	65,028	83,929	103,621	173.3%
	Santa Barbara (CA)	113,665	134,333	163,668	193,381	213,960	88.2%
	Ventura (CA)	131,954	166,800	216,109	259,345	320,927	143.2%
		3,745,743	4,068,736	4,916,015	5,429,007	6,097,552	62.8%
Fermi	Cook (IL)	2,780,014	2,742,358	2,873,797	2,885,969	3,080,458	10.8%
	De Kalb (IL)	31,128	31,702	34,187	35,438	38,832	24.7%
	Du Page (IL)	154,520	215,484	282,623	382,481	510,994	230.7%
	Kane (IL)	108,159	117,301	131,252	141,234	171,116	58.2%
	Kendall (IL)	13,871	16,224	17,041	13,700	10,763	-22.4%
	McHenry (IL)	41,314	46,505	55,262	65,007	81,866	98.2%
	Will (IL)	87,178	90,369	100,401	104,134	121,273	39.1%
		3,216,184	3,259,943	3,494,563	3,627,963	4,015,302	24.8%
FEMP	Butler (OH)	82,804	87,339	99,638	103,659	115,182	39.1%
	Hamilton (OH)	488,962	490,210	540,620	562,639	630,991	29.0%
	Warren (OH)	17,209	21,622	27,641	31,891	44,723	159.9%
	Dearborn (IN)	10,779	11,322	12,629	12,114	13,480	25.1%
		599,754	610,493	680,528	710,303	804,376	34.1%

Table C.4-18. Baseline Employment Data—Continued

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
GA	Imperial (CA)	33,842	41,879	45,988	40,725	52,289	54.5%
	Orange (CA)	531,119	711,851	1,038,731	1,271,121	1,552,291	192.3%
	Riverside (CA)	166,660	192,861	256,835	317,421	436,293	161.8%
	San Diego (CA)	633,738	733,668	963,302	1,154,677	1,396,552	120.4%
		1,365,359	1,680,259	2,304,856	2,783,944	3,437,425	151.8%
GE	Alpine (CA)	200	248	520	707	802	301.0%
	Amador (CA)	4,720	5,839	7,656	9,173	11,974	153.7%
	Calaveras (CA)	4,618	4,743	7,524	8,880	10,610	129.8%
	San Joaquin (CA)	123,076	139,076	162,927	181,349	211,109	71.5%
	Stanislaus (CA)	81,872	98,597	121,735	132,122	166,656	103.6%
	Tuolumne (CA)	7,473	9,570	13,817	16,582	20,641	176.2%
		221,959	258,073	314,179	348,813	421,792	90.0%
GJPO	Delta (CO)	5,515	6,599	8,667	9,155	9,506	72.4%
	Garfield (CO)	5,783	8,747	11,873	14,554	17,224	197.8%
	Gunnison (CO)	2,664	3,979	6,163	6,263	7,041	164.3%
	Mesa (CO)	22,275	29,506	42,466	43,106	48,064	115.8%
	Montrose (CO)	7,025	8,806	11,649	11,460	13,141	87.1%
	Pitkin (CO)	4,231	7,865	11,529	12,764	16,546	291.1%
	Grand (UT)	2,675	3,032	4,045	2,955	3,122	16.7%
		50,168	68,534	96,392	100,257	114,644	128.5%
Hanford	Adams (WA)	6,976	7,602	8,076	7,894	8,409	20.5%
	Benton (WA)	27,477	38,013	58,925	54,409	59,910	118.0%
	Franklin (WA)	12,743	15,528	18,414	17,177	21,129	65.8%
	Grant (WA)	18,323	22,333	23,340	23,904	26,950	47.1%
	Yakima (WA)	62,556	71,326	82,024	84,284	97,900	56.5%
		128,075	154,802	190,779	187,668	214,298	67.3%
INEL	Bannock (ID)	20,961	26,185	30,628	30,386	30,078	43.5%
	Bingham (ID)	12,362	14,051	15,150	15,679	16,758	35.6%
	Bonneville (ID)	22,232	26,706	31,452	33,436	38,092	71.3%
	Butte (ID)	4,287	5,347	6,625	7,054	7,934	85.1%
	Clark (ID)	463	539	602	584	679	46.7%
	Jefferson (ID)	4,221	4,953	5,603	5,470	6,151	45.7%
		64,526	77,781	90,060	92,609	99,692	54.5%
KCP	Cass (MO)	13,222	15,139	14,298	17,627	20,904	58.1%
	Clay (MO)	40,959	42,843	51,268	66,683	77,616	89.5%
	Jackson (MO)	385,262	390,795	424,126	430,173	441,174	14.5%
	Johnson (MO)	14,493	16,243	17,867	19,173	21,770	50.2%
	Lafayette (MO)	10,684	11,221	12,036	12,253	13,439	25.8%
	Ray (MO)	4,662	5,357	5,736	6,583	6,784	45.5%
	Johnson (KS)	70,399	98,553	141,148	185,482	242,894	245.0%
	Wyandotte (KS)	81,896	87,583	92,056	93,354	91,892	12.2%
		621,577	667,734	758,535	831,328	916,473	47.4%
KAPL-K	Fulton (NY)	18,714	18,882	19,715	20,262	21,167	13.1%
	Saratoga (NY)	30,254	35,894	44,418	54,378	68,058	125.0%
	Schenectady (NY)	71,461	75,442	75,567	75,564	79,628	11.4%
		120,429	130,218	139,700	150,204	168,853	40.2%
KAPL-N	Albany (NY)	179,332	183,478	203,657	225,005	256,215	42.9%
	Montgomery (NY)	22,062	20,904	22,387	23,284	24,092	9.2%
	Saratoga (NY)	30,254	35,894	44,418	54,378	68,058	125.0%
	Schenectady (NY)	71,461	75,442	75,567	75,564	79,628	11.4%
	Schoharie (NY)	7,799	8,514	8,656	9,267	10,655	36.6%
		310,908	324,232	354,685	387,498	438,648	41.1%
KAPL-W	Hartford (CT)	438,369	452,340	527,904	572,596	615,574	40.4%
	Litchfield (CT)	53,720	56,711	68,844	76,288	85,810	59.7%
	Middlesex (CT)	45,352	51,689	60,868	73,741	82,460	81.8%
	New Haven (CT)	337,150	345,124	380,393	414,784	444,307	31.8%
	Tolland (CT)	26,124	29,700	33,363	39,941	48,387	85.2%
	Hampden (MA)	202,106	198,347	220,977	229,234	240,374	18.9%
		1,102,821	1,133,911	1,292,349	1,406,584	1,516,912	37.5%

Table C.4-18. Baseline Employment Data—Continued

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
LEHR	Colusa (CA)	6,205	7,138	7,112	6,942	7,891	27.2%
	Lake (CA)	6,677	8,708	11,881	15,251	17,218	157.9%
	Napa (CA)	26,918	34,555	42,081	48,591	58,321	116.7%
	Sacramento (CA)	276,010	320,242	396,980	485,139	603,669	118.7%
	Solano (CA)	76,418	82,069	96,464	111,163	134,353	75.8%
	Sutter (CA)	15,427	19,256	22,441	22,643	26,725	73.2%
	Yolo (CA)	34,958	47,963	57,528	64,323	82,075	134.8%
		442,613	519,931	634,487	754,052	930,252	110.2%
LBL	Alameda (CA)	490,578	509,946	588,728	656,286	738,160	50.5%
	Contra Costa (CA)	170,808	202,758	262,043	321,605	396,508	132.1%
		661,386	712,704	850,771	977,891	1,134,668	71.6%
LLNL	Alameda (CA)	490,578	509,946	588,728	656,286	738,160	50.5%
	Contra Costa (CA)	170,808	202,758	262,043	321,605	396,508	132.1%
	San Joaquin (CA)	123,076	139,076	162,927	181,349	211,109	71.5%
	Stanislaus (CA)	81,872	98,597	121,735	132,122	166,656	103.6%
		866,334	950,377	1,135,433	1,291,362	1,512,433	74.6%
LANL	Los Alamos (NM)	8,802	10,950	14,010	16,831	18,066	105.2%
	Rio Arriba (NM)	6,505	7,006	8,303	9,377	10,341	59.0%
	Santa Fe (NM)	22,125	28,707	36,708	46,045	55,088	149.0%
		37,432	46,663	59,021	72,253	83,495	123.1%
Mare Island	Contra Costa (CA)	170,808	202,758	262,043	321,605	396,508	132.1%
	Lake (CA)	6,677	8,708	11,881	15,251	17,218	157.9%
	Marin (CA)	68,350	81,672	105,136	131,293	149,704	119.0%
	Mendocino (CA)	19,826	24,124	32,118	35,191	41,643	110.0%
	Napa (CA)	26,918	34,555	42,081	48,591	58,321	116.7%
	Sonoma (CA)	71,368	93,149	129,858	162,799	200,809	181.4%
		363,947	444,966	583,117	714,730	864,203	137.5%
Middlesex	Mercer (NJ)	152,536	163,220	180,825	197,963	218,289	43.1%
	Middlesex (NJ)	236,060	264,873	317,105	362,229	410,340	73.8%
	Monmouth (NJ)	156,505	173,172	205,799	247,685	278,379	77.9%
	Somerset (NJ)	73,129	87,696	110,237	138,071	162,850	122.7%
	Union (NJ)	289,170	276,194	298,539	312,241	298,021	3.1%
		907,400	965,155	1,112,505	1,258,189	1,367,879	50.7%
Mound	Butler (OH)	82,804	87,339	99,638	103,659	115,182	39.1%
	Clark (OH)	54,155	54,702	58,828	58,685	64,883	19.8%
	Darke (OH)	17,601	19,586	20,840	21,516	23,698	34.6%
	Greene (OH)	38,914	41,134	45,604	51,345	61,164	57.2%
	Miami (OH)	33,836	35,269	41,309	41,334	45,711	35.1%
	Montgomery (OH)	310,229	296,176	319,744	336,040	365,015	17.7%
	Preble (OH)	9,686	10,484	11,389	12,650	13,803	42.5%
	Warren (OH)	17,209	21,622	27,641	31,891	44,723	159.9%
		564,434	566,312	624,993	657,120	734,179	30.1%
NTS	Clark (NV)	131,904	171,122	261,135	301,329	441,267	234.5%
	Nye (NV)	7,140	5,794	7,819	11,071	12,763	78.8%
		139,044	176,916	268,954	312,400	454,030	226.5%
Norfolk	Chesapeake city (VA)	22,046	24,449	31,494	41,790	60,021	172.3%
	Hampton city (VA)	49,777	52,385	60,119	69,468	74,278	49.2%
	Newport News city (VA)	74,805	78,736	84,006	96,784	108,988	45.7%
	Norfolk city (VA)	209,849	211,839	225,741	245,270	256,042	22.0%
	Suffolk city (VA)	17,837	19,957	19,391	19,414	20,545	15.2%
	Virginia Beach city (VA)	64,219	77,602	106,903	151,809	182,932	184.9%
	Isle of Wight (VA)	9,222	9,781	11,791	11,380	12,346	33.9%
		447,755	474,749	539,445	635,915	715,152	59.7%
ORR	Anderson (TN)	20,457	24,385	30,785	32,310	39,083	91.1%
	Knox (TN)	123,389	143,530	174,676	187,012	212,347	72.1%
	Loudon (TN)	8,434	9,012	9,966	10,694	12,310	46.0%
	Roane (TN)	21,217	21,211	23,362	22,289	24,234	14.2%
		173,497	198,138	238,789	252,305	287,974	66.0%

Table C.4-18. Baseline Employment Data—Continued

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
PGDP	Ballard (KY)	3,139	3,344	3,812	3,603	3,868	23.2%
	Carlisle (KY)	1,911	1,814	1,768	1,798	1,802	-5.7%
	Graves (KY)	12,550	13,566	13,549	13,552	15,312	22.0%
	Marshall (KY)	9,121	9,125	10,705	10,901	12,773	40.0%
	McCracken (KY)	27,167	31,027	34,536	34,007	41,056	51.1%
	Massac (IL)	4,776	5,078	5,267	4,666	4,945	3.5%
		58,664	63,954	69,637	68,527	79,756	36.0%
Palos	Cook (IL)	2,780,014	2,742,358	2,873,797	2,885,969	3,080,458	10.8%
	Du Page (IL)	154,520	215,484	282,623	382,481	510,994	230.7%
	Kane (IL)	108,159	117,301	131,252	141,234	171,116	58.2%
	Lake (IL)	164,074	177,608	206,965	238,950	292,353	78.2%
	McHenry (IL)	41,314	46,505	55,262	65,007	81,866	98.2%
	Will (IL)	87,178	90,369	100,401	104,134	121,273	39.1%
	Lake (IN)	228,285	227,217	237,925	205,496	228,304	0.0%
		3,563,544	3,616,842	3,888,225	4,023,271	4,486,364	25.9%
Pantex	Carson (TX)	4,536	4,681	4,619	5,279	4,956	9.3%
	Potter (TX)	55,811	68,372	77,990	86,106	78,713	41.0%
	Randall (TX)	9,502	11,954	14,554	18,663	20,585	116.6%
		69,849	85,007	97,163	110,048	104,254	49.3%
Pearl H	Honolulu (HI)	354,084	400,793	454,443	474,056	540,449	52.6%
	Kauai (HI)	13,518	16,252	21,278	23,900	31,820	135.4%
	Maui (HI)	21,023	27,778	38,034	47,507	63,110	200.2%
		388,625	444,823	513,755	545,463	635,379	63.5%
Pinellas	Hillsborough (FL)	219,555	276,643	334,297	443,567	534,096	143.3%
	Pasco (FL)	17,603	30,096	46,570	66,730	83,624	375.1%
	Pinellas (FL)	185,693	232,451	307,786	400,674	457,517	146.4%
		422,851	539,190	688,653	910,971	1,075,237	154.3%
PORTS	Jackson (OH)	8,995	9,430	9,911	11,328	11,560	28.5%
	Pike (OH)	6,030	7,300	9,135	9,481	9,876	63.8%
	Ross (OH)	23,046	23,172	26,441	27,342	28,598	24.1%
	Scioto (OH)	26,467	24,934	26,633	25,617	27,772	4.9%
		64,538	64,836	72,120	73,768	77,806	20.6%
Ports Nav	Cumberland (ME)	97,734	107,768	126,806	151,907	183,271	87.5%
	Oxford (ME)	17,305	18,085	21,598	20,341	23,304	34.7%
	York (ME)	46,430	48,463	60,765	72,106	83,380	79.6%
	Carroll (NH)	8,070	10,525	14,020	18,809	23,172	187.1%
	Rockingham (NH)	49,342	60,202	89,598	117,970	134,660	172.9%
	Strafford (NH)	30,189	31,769	40,538	44,984	50,420	67.0%
		249,070	276,812	353,325	426,117	498,207	100.0%
PPPL	Burlington (NJ)	135,712	127,481	142,828	175,494	202,936	49.5%
	Hunterdon (NJ)	24,227	27,383	32,991	44,645	52,433	116.4%
	Mercer (NJ)	152,536	163,220	180,825	197,963	218,289	43.1%
	Middlesex (NJ)	236,060	264,873	317,105	362,229	410,340	73.8%
	Monmouth (NJ)	156,505	173,172	205,799	247,685	278,379	77.9%
	Somerset (NJ)	73,129	87,696	110,237	138,071	162,850	122.7%
	Bucks (PA)	137,592	163,917	199,483	234,165	266,078	93.4%
		915,761	1,007,742	1,189,268	1,400,252	1,591,305	73.8%
Puget So	Jefferson (WA)	3,628	4,405	6,183	7,114	9,117	151.3%
	King (WA)	537,408	605,581	804,356	901,911	1,131,447	110.5%
	Kitsap (WA)	44,510	50,766	66,838	78,435	95,238	114.0%
	Mason (WA)	6,919	8,067	10,767	11,274	13,333	92.7%
	Pierce (WA)	184,149	178,218	207,284	234,443	269,479	46.3%
		776,614	847,037	1,095,428	1,233,177	1,518,614	95.5%
RMI	Ashtabula (OH)	37,633	38,012	40,731	38,646	38,878	3.3%
	Geauga (OH)	15,640	18,878	23,400	28,035	32,720	109.2%
	Lake (OH)	62,584	72,178	86,842	90,650	103,431	65.3%
	Trumbull (OH)	95,326	102,895	107,783	102,098	105,424	10.6%
	Crawford (PA)	32,380	34,817	36,833	36,586	39,330	21.5%
	Erie (PA)	115,493	129,015	132,838	130,760	143,588	24.3%
		359,056	395,795	428,427	426,775	463,371	29.1%

Table C.4-18. Baseline Employment Data—Continued

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
RFETS	Adams (CO)	47,558	72,721	97,335	113,176	126,465	165.9%
	Arapahoe (CO)	48,565	87,125	132,994	191,619	218,287	349.5%
	Boulder (CO)	53,430	76,151	110,011	139,658	157,460	194.7%
	Denver (CO)	379,312	399,634	480,031	510,784	469,920	23.9%
	Jefferson (CO)	68,124	109,812	154,901	207,232	226,393	232.3%
		596,989	745,443	975,272	1,162,469	1,198,525	100.8%
SNL/NM	Bernalillo (NM)	135,635	176,533	219,901	266,864	304,985	124.9%
	Cibola (NM)	0	0	0	5,358	6,148	NA
	Sandoval (NM)	3,323	4,386	5,495	8,987	12,734	283.2%
	Santa Fe (NM)	22,125	28,707	36,708	46,045	55,088	149.0%
	Torrance (NM)	1,879	2,046	2,182	2,496	2,957	57.4%
	Valencia (NM)	9,110	12,208	17,661	9,695	11,486	26.1%
		172,072	223,880	281,947	339,445	393,398	128.6%
SRS	Aiken (SC)	35,181	38,587	45,585	52,476	73,012	107.5%
	Allendale (SC)	5,399	4,581	4,273	4,128	4,784	-11.4%
	Bamberg (SC)	6,327	6,268	6,691	6,118	6,139	-3.0%
	Barnwell (SC)	7,598	8,827	8,942	9,766	9,242	21.6%
	Burke (GA)	5,833	6,457	7,806	16,144	8,470	45.2%
	Columbia (GA)	21,949	15,829	22,958	26,033	28,284	28.9%
	Richmond (GA)	71,085	79,213	90,877	102,953	119,064	67.5%
	Screven (GA)	4,752	5,392	5,906	5,587	5,782	21.7%
		158,124	165,154	193,038	223,205	254,777	61.1%
SLAC	Alameda (CA)	490,578	509,946	588,728	656,286	738,160	50.5%
	Monterey (CA)	131,810	147,482	156,959	176,632	202,533	53.7%
	San Benito (CA)	7,902	9,020	10,481	11,808	15,212	92.5%
	San Mateo (CA)	227,090	259,528	313,958	349,819	396,533	74.6%
	Santa Clara (CA)	446,473	553,366	790,461	930,931	1,015,759	127.5%
	Santa Cruz (CA)	47,367	61,480	82,228	102,096	122,735	159.1%
	Stanislaus (CA)	81,872	98,597	121,735	132,122	166,656	103.6%
		1,433,092	1,639,419	2,064,550	2,359,694	2,657,588	85.4%
U of Mo	Audrain (MO)	12,400	12,868	13,518	12,386	12,779	3.1%
	Boone (MO)	39,057	46,023	56,810	63,584	75,366	93.0%
	Callaway (MO)	10,588	11,120	16,920	14,611	16,281	53.8%
	Cole (MO)	28,045	32,876	38,421	42,868	48,500	72.9%
	Cooper (MO)	6,488	6,913	6,965	7,026	7,097	9.4%
	Howard (MO)	4,866	4,555	4,190	4,364	4,421	-9.1%
	Moniteau (MO)	4,796	4,722	5,338	5,752	6,231	29.9%
	Randolph (MO)	8,977	9,883	11,321	12,350	12,666	41.1%
		115,217	128,960	153,483	162,941	183,341	59.1%
WIPP	Chaves (NM)	16,649	19,528	22,695	25,116	26,216	57.5%
	Eddy (NM)	15,825	18,410	21,374	22,298	21,748	37.4%
	Lea (NM)	20,607	23,894	29,280	30,095	25,009	21.4%
	Otero (NM)	19,079	20,526	22,626	25,681	24,956	30.8%
	Culberson (TX)	1,854	1,848	1,897	1,815	1,718	-7.3%
	Loving (TX)	102	175	131	123	60	-41.2%
		74,116	84,381	98,003	105,128	99,707	34.5%
WSSR	Franklin (MO)	19,479	22,207	27,656	31,825	38,233	96.3%
	Jefferson (MO)	19,773	21,857	29,787	38,875	47,635	140.9%
	St. Charles (MO)	23,441	29,902	40,985	66,107	83,286	255.3%
	St. Louis (MO)	355,947	393,919	477,764	610,547	695,600	95.4%
	Madison (IL)	97,430	96,639	100,691	99,640	112,247	15.2%
	Monroe (IL)	4,923	5,464	5,742	6,598	7,448	51.3%
	St. Clair (IL)	91,681	94,622	99,354	98,863	105,059	14.6%
		612,674	664,610	781,979	952,455	1,089,508	77.8%

Table C.4-18. Baseline Employment Data—Continued

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
WVDP	Cattaraugus (NY)	31,724	32,991	35,540	35,920	39,434	24.3%
	Erie (NY)	465,799	466,761	477,986	476,411	529,812	13.7%
		497,523	499,752	513,526	512,331	569,246	14.4%
UNITED STATES		89,753	97,177	112,257	123,176	137,160	52.8%

Notes: Ames = Ames Laboratory; ANL-E = Argonne National Laboratory-East; Bettis = Bettis Atomic Power Plant; BCL = Battelle Columbus Laboratories; BNL = Brookhaven National Laboratory; Charleston = Charleston Naval Shipyard; ETEC = Energy Technology Engineering Center; FEMP = Fernald Environmental Management Project; Fermi = Fermi National Accelerator Laboratory; GE = General Electric Vallecitos Nuclear Center; INEL = Idaho National Engineering Laboratory; KAPL-N = Knolls Atomic Power Laboratory (Niskayuna); LLNL = Lawrence Livermore National Laboratory; LANL = Los Alamos National Laboratory; GA = General Atomics; GJPO = Grand Junction Projects Office; KAPL-K = Knolls Atomic Power Laboratory (Kesselring); KAPL-W = Knolls Atomic Power Laboratory (Windsor); KCP = Kansas City Plant; LBL = Lawrence Berkeley National Laboratory; LEHR = Laboratory for Energy-Related Health Research; Mare Is = Mare Island Naval Shipyard; Middlesex = Middlesex Sampling Laboratory; Mound = Mound Plant; Norfolk = Norfolk Naval Shipyard; NTS = Nevada Test Site; ORR = Oak Ridge Reservation; Palos = Palos Forest; Pearl H = Pearl Harbor Naval Shipyard; PGDP = Paducah Gaseous Diffusion Plant; PORTS = Portsmouth Gaseous Diffusion Plant; Ports Nav = Portsmouth Naval Shipyard; PPPL = Princeton Plasma Physics Laboratory; Puget So = Puget Sound Naval Shipyard; RFETS = Rocky Flats Environmental Technology Site; RMI = Reactive Metals, Inc.; SLAC = Stanford Linear Accelerator System; SNL/NM = Sandia National Laboratories (New Mexico); SRS = Savannah River Site; UofMO = University of Missouri; WIPP = Waste Isolation Pilot Plant; WSSR = Weldon Spring Site Remedial Action Project; and WVDP = West Valley Demonstration Project.

Source: U.S. Department of Commerce (1992a).

C.4.5.3 Impacts Analysis Procedures

C.4.5.3.1 *Development of Regional Multipliers*

The economic impact analysis was conducted by first determining how responsive the National economy and the various regional economies were to a change in expenditures. The result of this determination was quantified in what is termed a "multiplier." Each site has a unique ROI (relevant counties as defined below) and each industry within that region has a unique degree of responsiveness to changes in the level of expenditures in the region. Multipliers for disposable income, output, and job-years were developed for 80 industries (industrial sectors) for the aggregate county regions of influence and the national economy. The multipliers were derived from an 80-sector model based on the Regional Input-Output Modeling System (RIMS II) approach developed by the U.S. Department of Commerce, Bureau of Economic Analysis (DOC, 1992b).

The procedure for developing the regional multipliers required establishing an economic ROI for each site. This was done by identifying those counties in the vicinity of the site where economic impacts would be expected to occur. Counties are unique in their ability to provide the labor and other resources necessary to any particular line of production. The demand for intermediate goods (i.e., goods that are used in the production of other goods) is a function of the demand for final goods. The technique used to measure a county's ability to satisfy production requirements was first to establish the relationships between industries

Table C.4-19. Baseline Personal Income

Total Personal Income ($ million)

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
Ames	Boone (IA)	98.6	168.7	261.4	324.0	402.3	308.1%
	Hamilton (IA)	74.5	128.7	190.3	246.3	314.7	322.6%
	Hardin (IA)	92.0	141.9	215.9	276.2	333.6	262.7%
	Jasper (IA)	142.1	228.1	356.8	485.9	634.1	346.2%
	Marshall (IA)	182.4	290.9	433.1	539.1	692.8	279.8%
	Polk (IA)	1,268.0	2,073.2	3,444.2	4,703.3	6,620.9	422.1%
	Story (IA)	210.3	354.0	633.2	879.5	1,180.8	461.6%
		2,067.9	3,385.5	5,534.9	7,454.2	10,179.3	392.3%
ANL-E	Cook (IL)	27,609.0	39,409.7	60,465.2	82,068.1	110,927.8	301.8%
	Du Page (IL)	2,611.0	4,636.8	9,007.3	13,480.1	21,043.2	706.0%
	Kane (IL)	1,169.8	1,863.4	3,117.7	4,490.1	6,914.2	491.0%
	Will (IL)	1,068.0	1,844.2	3,372.3	4,633.2	6,738.2	530.9%
		32,457.8	47,754.1	75,962.5	104,671.5	145,623.4	348.7%
BCL	Delaware (OH)	159.0	281.1	510.6	799.7	1,279.4	704.5%
	Fairfield (OH)	263.5	456.6	848.7	1,219.1	1,697.2	544.1%
	Franklin (OH)	3,449.1	5,284.4	8,639.7	12,854.9	18,376.0	432.8%
	Licking (OH)	374.3	617.4	1,088.2	1,566.7	2,109.6	463.6%
	Madison (OH)	100.3	169.6	275.1	385.7	580.5	478.6%
	Pickaway (OH)	135.1	221.6	354.5	488.5	666.3	393.2%
	Union (OH)	89.0	155.0	267.8	384.4	618.8	595.2%
		4,570.4	7,185.5	11,984.7	17,698.9	25,327.8	454.2%
Bettis	Allegheny (PA)	7,024.7	10,277.7	16,072.4	20,701.8	27,600.6	292.9%
	Armstrong (PA)	243.3	415.6	691.0	929.1	1,228.3	404.8%
	Beaver (PA)	742.2	1,236.9	2,061.3	2,261.5	2,816.5	279.5%
	Butler (PA)	474.9	785.4	1,384.4	1,834.4	2,626.3	453.0%
	Washington (PA)	759.5	1,246.5	2,066.4	2,584.4	3,396.7	347.2%
	Westmoreland (PA)	1,383.8	2,153.6	3,803.4	4,816.0	6,316.2	356.4%
		10,628.3	16,115.6	26,078.8	33,127.3	43,984.7	313.8%
BNL	Nassau (NY)	8,524.6	11,845.3	18,941.6	28,244.9	40,745.2	378.0%
	Suffolk (NY)	4,876.5	7,924.0	13,650.9	21,596.1	32,091.6	558.1%
		13,401.1	19,769.3	32,592.5	49,840.9	72,836.8	443.5%
Charleston	Berkeley (SC)	145.2	301.4	635.6	1,116.0	1,672.5	1051.5%
	Charleston (SC)	835.3	1,363.4	2,236.8	3,280.0	4,741.6	467.6%
	Colleton (SC)	65.6	110.9	196.7	282.0	407.9	521.6%
	Dorchester (SC)	95.5	201.6	461.7	769.4	1,175.2	1130.0%
		1,141.7	1,977.4	3,530.8	5,447.5	7,997.2	600.4%
Colonie	Albany (NY)	1,378.0	2,028.6	3,027.7	4,382.5	6,147.6	346.1%
	Columbia (NY)	194.8	325.4	564.1	846.2	1,239.0	536.0%
	Greene (NY)	123.8	204.4	341.3	496.2	735.9	494.4%
	Rensselaer (NY)	574.8	827.5	1,306.1	1,907.1	2,745.3	377.7%
	Saratoga (NY)	437.1	738.5	1,374.4	2,153.7	3,435.4	686.0%
	Schenectady (NY)	738.5	1,025.3	1,544.5	2,243.2	3,086.2	317.9%
	Schoharie (NY)	85.1	131.6	210.6	302.6	455.6	435.6%
		3,532.0	5,281.4	8,368.7	12,331.4	17,845.0	405.2%
ETEC	Kern (CA)	1,267.9	2,189.1	4,321.3	6,224.1	8,691.4	585.5%
	Los Angeles (CA)	35,043.2	50,436.0	88,053.0	130,394.8	185,131.4	428.3%
	San Luis Obispo (CA)	388.3	718.0	1,443.5	2,469.8	3,767.8	870.3%
	Santa Barbara (CA)	1,235.4	1,949.3	3,563.0	5,696.0	8,134.3	558.4%
	Ventura (CA)	1,589.4	2,901.8	5,940.7	9,495.6	14,428.4	807.8%
		39,524.2	58,194.3	103,321.5	154,280.3	220,153.3	457.0%

Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
Fermi	Cook (IL)	27,609.0	39,409.7	60,465.2	82,068.1	110,927.8	301.8%
	De Kalb (IL)	264.8	431.7	675.2	935.5	1,286.3	385.8%
	Du Page (IL)	2,611.0	4,636.8	9,007.3	13,480.1	21,043.2	706.0%
	Kane (IL)	1,169.8	1,863.4	3,117.7	4,490.1	6,914.2	491.0%
	Kendall (IL)	122.6	226.6	425.2	549.7	797.7	550.6%
	McHenry (IL)	519.0	895.6	1,677.4	2,509.2	4,032.9	677.1%
	Will (IL)	1,068.0	1,844.2	3,372.3	4,633.2	6,738.2	530.9%
		33,364.2	49,307.9	78,740.3	108,665.9	151,740.3	354.8%
FEMP	Butler (OH)	870.5	1,386.6	2,508.2	3,473.1	4,902.0	463.1%
	Hamilton (OH)	4,130.7	5,879.9	9,405.5	12,973.0	17,837.8	331.8%
	Warren (OH)	302.0	476.2	890.9	1,271.3	1,973.6	553.6%
	Dearborn (IN)	101.0	162.8	295.4	430.2	594.3	488.4%
		5,404.2	7,905.5	13,099.9	18,147.7	25,307.8	368.3%
GA	Imperial (CA)	299.6	527.9	888.2	1,085.6	1,595.3	432.4%
	Orange (CA)	7,013.6	12,242.3	25,407.5	40,169.6	59,190.7	743.9%
	Riverside (CA)	2,012.5	3,522.1	7,104.1	11,674.0	20,431.5	915.2%
	San Diego (CA)	6,163.1	10,294.5	19,917.7	32,190.3	49,344.3	700.6%
		15,488.9	26,586.7	53,317.4	85,119.4	130,561.8	742.9%
GE	Alpine (CA)	2.1	4.1	9.2	15.4	25.5	1093.0%
	Amador (CA)	49.0	89.4	188.3	292.7	456.0	830.6%
	Calaveras (CA)	51.6	86.1	184.4	294.0	442.3	757.8%
	San Joaquin (CA)	1,215.3	2,033.7	3,634.5	5,215.1	7,484.0	515.8%
	Stanislaus (CA)	766.1	1,335.7	2,577.1	3,743.3	5,699.3	644.0%
	Tuolumne (CA)	81.5	144.9	308.1	481.9	724.9	789.9%
		2,165.5	3,693.8	6,901.6	10,042.2	14,832.0	584.9%
GJPO	Delta (CO)	45.8	84.7	168.8	229.5	278.8	508.9%
	Garfield (CO)	56.6	115.9	236.2	335.4	486.7	759.5%
	Gunnison (CO)	18.1	36.2	80.5	109.7	139.9	674.4%
	Mesa (CO)	183.4	365.3	805.0	1,041.8	1,412.7	670.2%
	Montrose (CO)	53.3	97.5	186.2	253.7	350.9	558.6%
	Pitkin (CO)	36.0	79.9	169.4	249.0	412.7	1047.6%
	Grand (UT)	23.1	37.5	77.9	76.8	88.0	280.6%
		416.3	817.0	1,724.1	2,295.8	3,169.8	661.5%
Hanford	Adams (WA)	54.7	122.5	146.2	184.3	230.7	321.6%
	Benton (WA)	269.5	536.2	1,200.8	1,473.4	1,959.2	626.9%
	Franklin (WA)	98.0	197.9	358.6	409.2	553.1	464.6%
	Grant (WA)	148.4	296.4	444.2	601.8	853.8	475.2%
	Yakima (WA)	496.0	929.0	1,549.3	2,046.8	2,920.4	488.8%
		1,066.7	2,082.0	3,699.2	4,715.4	6,517.2	511.0%
INEL	Bannock (ID)	169.4	310.5	554.3	731.3	884.6	422.1%
	Bingham (ID)	93.5	161.6	266.2	353.4	512.5	448.0%
	Bonneville (ID)	189.5	339.7	588.5	837.4	1,203.7	535.2%
	Butte (ID)	9.5	14.0	28.2	32.2	45.8	380.6%
	Clark (ID)	4.7	6.1	10.1	12.7	20.2	327.9%
	Jefferson (ID)	34.6	61.4	106.7	136.6	212.2	512.8%
		501.3	893.2	1,554.0	2,103.7	2,879.0	474.3%
KCP	Cass (MO)	132.6	250.9	484.7	753.2	1,092.3	724.1%
	Clay (MO)	501.9	784.7	1,467.5	2,172.1	2,833.8	464.6%
	Jackson (MO)	2,825.6	4,181.1	6,531.9	9,141.2	11,798.7	317.6%
	Johnson (MO)	104.7	160.3	261.7	381.3	521.4	397.9%
	Lafayette (MO)	103.7	161.5	264.7	381.7	504.7	386.6%
	Ray (MO)	61.0	102.1	187.6	271.4	335.7	450.4%
	Johnson (KS)	1,151.1	1,940.2	3,776.0	5,973.0	9,355.4	712.7%
	Wyandotte (KS)	650.3	944.2	1,479.1	1,941.4	2,284.9	251.4%
		5,530.9	8,525.0	14,453.1	21,015.4	28,726.9	419.4%

Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
KAPL-K	Fulton (NY)	189.8	279.0	448.1	619.9	849.2	347.5%
	Saratoga (NY)	437.1	738.5	1,374.4	2,153.7	3,435.4	686.0%
	Schenectady (NY)	738.5	1,025.3	1,544.5	2,243.2	3,086.2	317.9%
		1,365.4	2,042.7	3,367.0	5,016.7	7,370.7	439.8%
KAPL-N	Albany (NY)	1,378.0	2,028.6	3,027.7	4,382.5	6,147.6	346.1%
	Montgomery (NY)	210.7	290.7	446.5	599.3	835.0	296.4%
	Saratoga (NY)	437.1	738.5	1,374.4	2,153.7	3,435.4	686.0%
	Schenectady (NY)	738.5	1,025.3	1,544.5	2,243.2	3,086.2	317.9%
	Schoharie (NY)	85.1	131.6	210.6	302.6	455.6	435.6%
		2,849.3	4,214.7	6,603.7	9,681.2	13,959.8	389.9%
KAPL-W	Hartford (CT)	4,109.6	5,812.0	9,720.2	14,610.2	21,209.3	416.1%
	Litchfield (CT)	689.5	1,053.0	1,876.1	2,905.6	4,391.3	536.9%
	Middlesex (CT)	535.9	837.8	1,452.3	2,279.9	3,462.3	546.0%
	New Haven (CT)	3,509.0	5,060.5	8,305.2	12,501.4	17,872.5	409.3%
	Tolland (CT)	412.0	622.6	1,167.7	1,826.0	2,831.8	587.3%
	Hampden (MA)	1,866.9	2,696.5	4,323.7	6,220.6	8,706.2	366.4%
		11,122.9	16,082.3	26,845.1	40,343.8	58,473.4	425.7%
LEHR	Colusa (CA)	73.5	143.5	178.3	205.3	278.4	278.7%
	Lake (CA)	77.1	150.6	349.4	559.9	789.4	924.2%
	Napa (CA)	362.2	638.6	1,145.6	1,712.0	2,519.8	595.8%
	Sacramento (CA)	2,766.4	4,513.4	8,310.2	12,912.8	19,873.9	618.4%
	Solano (CA)	695.7	1,252.9	2,402.7	3,749.2	5,935.3	753.2%
	Sutter (CA)	187.1	346.9	557.4	743.3	1,032.1	451.7%
	Yolo (CA)	407.3	734.0	1,239.1	1,775.7	2,801.9	588.0%
		4,569.1	7,779.8	14,182.8	21,658.2	33,230.9	627.3%
LBL	Alameda (CA)	5,187.3	7,674.5	13,092.7	20,275.5	28,453.8	448.5%
	Contra Costa (CA)	2,774.2	4,452.6	8,785.0	13,924.1	20,647.5	644.3%
		7,961.5	12,127.2	21,877.7	34,199.6	49,101.3	516.7%
LLNL	Alameda (CA)	5,187.3	7,674.5	13,092.7	20,275.5	28,453.8	448.5%
	Contra Costa (CA)	2,774.2	4,452.6	8,785.0	13,924.1	20,647.5	644.3%
	San Joaquin (CA)	1,215.3	2,033.7	3,634.5	5,215.1	7,484.0	515.8%
	Stanislaus (CA)	766.1	1,335.7	2,577.1	3,743.3	5,699.3	644.0%
		9,942.9	15,496.5	28,089.2	43,157.9	62,284.6	526.4%
LANL	Los Alamos (NM)	78.1	124.7	221.4	364.4	505.8	547.8%
	Rio Arriba (NM)	53.8	92.1	163.6	240.3	312.1	480.0%
	Santa Fe (NM)	192.8	352.3	677.2	1,140.1	1,704.0	784.0%
		324.7	569.1	1,062.1	1,744.8	2,521.9	676.8%
Mare Is	Contra Costa (CA)	2,774.2	4,452.6	8,785.0	13,924.1	20,647.5	644.3%
	Lake (CA)	77.1	150.6	349.4	559.9	789.4	924.2%
	Marin (CA)	1,229.1	1,945.1	3,813.8	6,056.3	8,657.2	604.3%
	Mendocino (CA)	195.4	329.5	650.2	900.8	1,301.1	565.8%
	Napa (CA)	362.2	638.6	1,145.6	1,712.0	2,519.8	595.8%
	Sonoma (CA)	921.5	1,694.7	3,430.8	5,556.0	8,628.9	836.4%
		5,559.5	9,211.0	18,174.8	28,709.0	42,543.9	665.3%
Middlesex	Mercer (NJ)	1,475.4	2,314.5	3,647.9	5,707.3	8,491.9	475.6%
	Middlesex (NJ)	2,751.4	4,303.7	7,057.0	11,558.7	16,761.1	509.2%
	Monmouth (NJ)	2,120.8	3,380.2	6,038.3	10,105.8	15,178.4	615.7%
	Somerset (NJ)	1,055.7	1,604.0	2,919.1	4,991.5	8,009.3	658.7%
	Union (NJ)	3,002.8	4,035.9	6,505.8	9,621.6	12,943.0	331.0%
		10,406.1	15,638.3	26,168.1	41,984.8	61,383.7	489.9%

Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
Mound	Butler (OH)	870.5	1,386.6	2,508.2	3,473.1	4,902.0	463.1%
	Clark (OH)	588.0	853.4	1,331.4	1,832.4	2,461.8	318.7%
	Darke (OH)	175.2	277.8	463.8	641.3	864.6	393.4%
	Greene (OH)	502.0	750.2	1,243.6	1,742.3	2,490.0	396.0%
	Miami (OH)	337.8	502.0	860.2	1,171.6	1,585.3	369.3%
	Montgomery (OH)	2,630.1	3,625.9	5,742.2	7,999.6	10,577.1	302.2%
	Preble (OH)	123.9	188.0	320.9	444.0	598.6	383.0%
	Warren (OH)	302.0	476.2	890.9	1,271.3	1,973.6	553.6%
		5,529.5	8,060.0	13,361.3	18,575.6	25,453.1	360.3%
NTS	Clark (NV)	1,335.2	2,337.6	5,123.0	7,843.2	14,087.5	955.1%
	Nye (NV)	27.6	44.6	100.3	167.9	273.9	892.9%
		1,362.8	2,382.2	5,223.3	8,011.0	14,361.4	953.8%
Norfolk	Chesapeake city (VA)	296.6	537.7	1,025.5	1,672.3	2,593.7	774.4%
	Hampton city (VA)	420.2	648.9	1,006.2	1,513.1	1,979.0	371.0%
	Newport News city (VA)	490.8	753.8	1,281.5	1,985.1	2,613.3	432.5%
	Norfolk city (VA)	1,111.8	1,610.3	2,339.9	3,389.0	4,280.1	285.0%
	Suffolk city (VA)	139.3	244.5	407.5	635.0	878.2	530.3%
	Virginia Beach city (VA)	690.0	1,354.7	2,707.1	4,745.4	7,024.8	918.0%
	Isle of Wight (VA)	57.0	105.1	191.2	313.7	451.6	692.2%
		3,205.7	5,255.0	8,958.9	14,253.5	19,820.6	518.3%
ORR	Anderson (TN)	203.2	346.8	586.1	801.7	1,121.1	451.6%
	Knox (TN)	923.2	1,562.5	2,788.6	4,045.7	5,844.4	533.1%
	Loudon (TN)	66.9	117.2	218.8	293.0	433.5	547.5%
	Roane (TN)	110.5	199.2	395.6	527.8	727.5	558.2%
		1,303.9	2,225.7	3,989.2	5,668.2	8,126.4	523.2%
PGDP	Ballard (KY)	27.8	41.9	70.6	88.7	122.9	342.3%
	Carlisle (KY)	13.9	22.9	37.5	52.9	66.1	374.1%
	Graves (KY)	93.0	150.4	266.5	355.9	482.0	418.4%
	Marshall (KY)	61.7	107.4	215.1	287.2	398.7	545.8%
	McCracken (KY)	209.4	335.7	588.6	777.3	1,099.4	425.1%
	Massac (IL)	41.4	71.8	113.5	151.3	195.3	372.3%
		447.2	730.2	1,291.8	1,713.3	2,364.5	428.8%
Palos	Cook (IL)	27,609.0	39,409.7	60,465.2	82,068.1	110,927.8	301.8%
	Du Page (IL)	2,611.0	4,636.8	9,007.3	13,480.1	21,043.2	706.0%
	Kane (IL)	1,169.8	1,863.4	3,117.7	4,490.1	6,914.2	491.0%
	Lake (IL)	1,980.9	3,214.4	5,837.8	8,946.3	14,211.2	617.4%
	McHenry (IL)	519.0	895.6	1,677.4	2,509.2	4,032.9	677.1%
	Will (IL)	1,068.0	1,844.2	3,372.3	4,633.2	6,738.2	530.9%
	Lake (IN)	2,159.4	3,257.7	5,187.4	5,916.4	7,758.7	259.3%
		37,117.1	55,121.9	88,665.1	122,043.4	171,626.2	362.4%
Pantex	Carson (TX)	27.2	67.5	63.0	99.1	117.7	332.1%
	Potter (TX)	315.2	512.3	958.9	1,357.7	1,589.1	404.1%
	Randall (TX)	233.3	448.3	768.8	1,295.3	1,598.0	585.0%
		575.7	1,028.2	1,790.7	2,752.0	3,304.7	474.0%
Pearl H	Honolulu (HI)	3,194.4	5,090.3	8,293.1	11,815.8	17,880.7	459.8%
	Kauai (HI)	121.2	207.8	374.4	515.8	884.1	629.5%
	Maui (HI)	193.9	371.9	710.5	1,068.6	1,876.8	867.7%
		3,509.5	5,670.1	9,377.9	13,400.2	20,641.6	488.2%
Pinellas	Hillsborough (FL)	1,683.7	3,130.5	5,593.9	9,497.0	14,177.8	742.1%
	Pasco (FL)	249.7	650.0	1,562.5	2,703.0	3,960.7	1486.4%
	Pinellas (FL)	2,189.0	4,014.7	7,710.5	12,857.5	18,483.7	744.4%
		4,122.3	7,795.2	14,866.9	25,057.5	36,622.1	788.4%

Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
PORTS	Jackson (OH)	72.1	119.0	201.6	279.2	347.6	382.2%
	Pike (OH)	48.3	81.3	146.2	219.3	291.7	503.6%
	Ross (OH)	194.9	300.8	529.4	737.0	935.8	380.1%
	Scioto (OH)	247.0	364.1	608.4	788.9	1,017.3	311.9%
		562.3	865.1	1,485.6	2,024.4	2,592.4	361.0%
Ports Nav	Cumberland (ME)	766.5	1,192.3	2,041.5	3,270.8	5,211.5	579.9%
	Oxford (ME)	139.9	216.5	391.7	528.2	786.0	462.0%
	York (ME)	399.4	629.7	1,187.1	1,896.6	2,960.5	641.2%
	Carroll (NH)	73.7	134.3	267.1	461.5	780.8	959.5%
	Rockingham (NH)	536.8	904.9	1,957.5	3,566.5	5,369.4	900.3%
	Strafford (NH)	245.0	368.3	735.1	1,195.7	1,794.5	632.5%
		2,161.3	3,446.0	6,580.0	10,919.3	16,902.6	682.1%
PPPL	Burlington (NJ)	1,326.0	2,172.7	3,897.1	6,067.2	9,106.0	586.7%
	Hunterdon (NJ)	344.2	600.8	1,139.9	2,043.2	3,276.3	852.0%
	Mercer (NJ)	1,475.4	2,314.5	3,647.9	5,707.3	8,491.9	475.6%
	Middlesex (NJ)	2,751.4	4,303.7	7,057.0	11,558.7	16,761.1	509.2%
	Monmouth (NJ)	2,120.8	3,380.2	6,038.3	10,105.8	15,178.4	615.7%
	Somerset (NJ)	1,055.7	1,604.0	2,919.1	4,991.5	8,009.3	658.7%
	Bucks (PA)	1,754.2	2,875.8	5,280.3	8,132.8	12,250.6	598.3%
		10,827.6	17,251.7	29,979.6	48,606.4	73,073.7	574.9%
Puget So	Jefferson (WA)	39.3	71.1	156.3	226.7	329.2	738.1%
	King (WA)	5,583.1	8,507.6	16,470.2	23,445.3	36,181.4	548.1%
	Kitsap (WA)	430.4	761.3	1,485.0	2,232.2	3,262.1	657.9%
	Mason (WA)	75.2	135.1	279.3	390.6	547.2	628.0%
	Pierce (WA)	1,654.8	2,561.0	4,738.9	6,764.8	9,583.1	479.1%
		7,782.8	12,036.2	23,129.8	33,059.5	49,903.0	541.2%
RMI	Ashtabula (OH)	347.8	526.1	875.2	1,102.7	1,337.9	284.7%
	Geauga (OH)	256.8	415.1	826.7	1,164.4	1,688.0	557.4%
	Lake (OH)	823.6	1,276.0	2,270.5	3,096.8	4,249.0	415.9%
	Trumbull (OH)	935.6	1,494.9	2,400.7	2,937.9	3,673.6	292.7%
	Crawford (PA)	281.0	443.6	715.2	937.7	1,241.6	341.8%
	Erie (PA)	1,015.4	1,623.4	2,544.8	3,358.2	4,499.4	343.1%
		3,660.2	5,779.1	9,633.2	12,597.8	16,689.5	356.0%
RFETS	Adams (CO)	659.4	1,151.3	2,288.6	3,461.4	4,274.6	548.2%
	Arapahoe (CO)	805.9	1,704.1	3,826.3	6,567.0	8,850.0	998.2%
	Boulder (CO)	556.8	1,005.4	2,125.7	3,479.2	4,843.5	769.9%
	Denver (CO)	2,469.1	3,830.5	6,029.7	8,610.0	10,334.9	318.6%
	Jefferson (CO)	1,081.0	2,119.6	4,484.6	7,245.9	9,230.5	753.9%
		5,572.1	9,810.9	18,754.9	29,363.5	37,533.5	573.6%
SNL/NM	Bernalillo (NM)	1,158.1	2,088.6	3,895.3	6,168.0	8,450.7	629.7%
	Cibola (NM)	0.0	0.0	0.0	175.4	195.2	NA
	Sandoval (NM)	40.1	102.1	227.3	488.0	832.9	1974.7%
	Santa Fe (NM)	192.8	352.3	677.2	1,140.1	1,704.0	784.0%
	Torrance (NM)	13.4	25.7	52.6	76.1	107.9	703.1%
	Valencia (NM)	97.1	179.2	436.2	369.9	532.2	448.0%
		1,501.5	2,747.9	5,288.6	8,417.4	11,822.9	687.4%

Table C.4-19. Baseline Personal Income—Continued

Total Personal Income ($ million)

Site	County/State	1970	1975	1980	1985	1990	Percent Change 1970-1990
SRS	Aiken (SC)	306.6	484.2	860.5	1,359.6	2,172.4	608.6%
	Allendale (SC)	21.5	35.1	59.3	88.5	127.5	493.5%
	Bamberg (SC)	36.6	59.8	92.7	134.5	177.3	384.8%
	Barnwell (SC)	46.3	84.1	129.4	209.5	285.8	517.2%
	Burke (GA)	44.7	76.7	120.3	199.7	231.1	417.4%
	Columbia (GA)	70.8	131.7	339.9	694.8	1,120.6	1483.3%
	Richmond (GA)	500.3	820.7	1,369.8	2,233.2	3,023.5	504.3%
	Screven (GA)	28.7	52.3	80.7	130.8	165.9	477.2%
		1,055.4	1,744.5	3,052.6	5,050.6	7,304.0	592.0%
SLAC	Alameda (CA)	5,187.3	7,674.5	13,092.7	20,275.5	28,453.8	448.5%
	Monterey (CA)	1,167.5	1,915.6	3,178.0	4,826.1	6,954.0	495.6%
	San Benito (CA)	73.5	124.1	246.3	391.9	600.5	716.6%
	San Mateo (CA)	3,277.2	4,970.5	8,595.9	13,341.5	18,789.9	473.4%
	Santa Clara (CA)	5,220.4	8,610.2	16,910.5	27,071.3	37,882.5	625.7%
	Santa Cruz (CA)	541.6	1,011.8	2,087.0	3,323.7	5,085.9	839.1%
	Stanislaus (CA)	766.1	1,335.7	2,577.1	3,743.3	5,699.3	644.0%
		16,233.6	25,642.4	46,687.6	72,973.3	103,465.8	537.4%
UofMO	Audrain (MO)	91.1	139.7	224.2	288.2	355.5	290.3%
	Boone (MO)	269.9	474.9	890.4	1,320.1	1,935.4	617.1%
	Callaway (MO)	84.6	131.5	268.3	368.3	487.9	476.6%
	Cole (MO)	172.1	286.7	507.7	745.4	1,038.5	503.3%
	Cooper (MO)	51.6	77.6	115.8	161.5	202.6	292.3%
	Howard (MO)	33.8	47.1	72.3	103.1	129.9	284.8%
	Moniteau (MO)	34.2	56.4	97.2	138.3	190.8	458.0%
	Randolph (MO)	73.0	117.4	187.8	266.2	330.5	353.0%
		810.2	1,331.1	2,363.8	3,391.0	4,670.9	476.5%
WIPP	Chaves (NM)	135.7	240.6	416.7	626.9	821.6	505.5%
	Eddy (NM)	130.7	225.6	409.7	585.9	688.8	427.1%
	Lea (NM)	167.1	289.6	558.2	778.5	744.5	345.6%
	Otero (NM)	125.1	200.2	322.4	520.4	651.7	421.0%
	Culberson (TX)	11.1	16.0	27.3	32.5	38.0	242.8%
	Loving (TX)	0.4	1.1	2.1	2.1	2.7	507.2%
		570.1	973.1	1,736.3	2,546.3	2,947.3	417.0%
WSSR	Franklin (MO)	189.3	316.9	614.9	956.8	1,323.3	598.9%
	Jefferson (MO)	350.2	549.8	1,271.3	1,923.6	2,737.9	681.7%
	St. Charles (MO)	372.9	606.0	1,454.9	2,610.8	4,036.8	982.5%
	St. Louis (MO)	4,885.5	7,329.9	11,901.7	17,713.2	24,097.6	393.2%
	Madison (IL)	995.1	1,470.2	2,459.0	3,350.6	4,487.0	350.9%
	Monroe (IL)	66.2	109.7	212.4	307.2	465.9	603.5%
	St. Clair (IL)	1,013.4	1,480.5	2,373.8	3,275.2	4,257.3	320.1%
		7,872.7	11,862.9	20,287.9	30,137.3	41,405.8	425.9%
WVDP	Cattaraugus (NY)	269.9	405.5	633.5	850.3	1,152.5	327.1%
	Erie (NY)	4,669.4	6,608.2	10,002.6	13,224.0	17,712.0	279.3%
		4,939.2	7,013.7	10,636.1	14,074.2	18,864.5	281.9%
UNITED STATES		825,534.0	1,308,482.0	2,254,076.0	3,317,545.0	4,664,057.0	465.0%

Source: U.S. Department of Commerce, Bureau of Economic Analysis (1992a).

for the National economy, and then to estimate the proportion of relationships that are attributable to the regional economy under analysis. The technique involves matrix multiplication of the Bureau of Economic Analysis' 1987 *Use and Make Tables* (DOC, 1994) that results in a *National Direct Requirements Table*, as shown in the following example:

$$A_N = [USE_N] \times [MAKE_N]$$

where:

A_N = National Direct Requirements Table,

USE_N = 1987 U.S. Use Table, and

$MAKE_N$ = 1987 U.S. Make Table.

By using the Consumer Price Index (CPI) and the Producer Price Index (PPI), the 1987 data was updated to 1990 dollar terms. (The detailed PPI was used to update manufacturing and wholesale trade sectors, while the detailed CPI was used to update service and retail sectors.)

Once the interindustry relationships were identified in the *National Direct Requirements Table*, they were regionalized by calculating the location quotient for earnings (i.e., income to labor). The location quotient for output is given by:

$$LQ^R_i = [(X^R_i/X^R)/(X^N_i/X^N)]$$

where:

LQ^R = Location quotient for region "R" and industry "i,"

X^R_i and X^R = output for industry "i" and total industry output in the region, and

X^N_i and X^N = National output for industry "i" and total output for the country (Miller and Blair, 1985).

Similarly, the income (earnings) location quotient matrix for industry "i" in region "R" is given by:

$$LQ^R_i = [(Y^R_i/Y^R)/(Y^N_i/Y^N)]$$

where:

LQ^R = Location quotient for region "R" and industry "i,"

Y^n and Y^n = national income for industry "i" and total income for the Nation, and

Y^R_i and Y^R = income for industry "i" and total industry income in the region.

The *National Direct Requirements Table* (from above) was then multiplied by the vector of location quotients for a given region to derive a regional *Direct Requirements Table*. This process was repeated for each ROI.

The regional *Direct Requirements Table* is therefore:

$$A_R = [LQ_R] \times [A_N]$$

where:

A_R = regional Direct Requirements Table for region "R," and

LQ_R = Matrix of location quotients for region "R".

The following calculation resulted in the final matrix of impacts for a given region:

$$M_R = [I - A_R]^{-1}$$

where:

M_R = matrix of output multipliers for region "R," and

I = the "identity" matrix (a matrix of zeros with ones on the diagonal).

The resulting 80-by-80-sector output multiplier table was then totaled across its rows (except for row 80) to produce a vector of output multipliers. Row 80 is the sum of earnings paid to households and is already incorporated in the multipliers for the first 79 sectors. Therefore, row 80 contains the earnings multipliers for a given region.

A final step was required to determine the employment multipliers for a region. Using County Business Pattern data for the Nation as a whole (DOC, 1993), the relationships between employment and output for all industries were derived.

The standard procedure in applying regional impact models is to calculate the specific multipliers (employment, income, and output as described above) for each of the 80 sectors individually, then multiply each industry multiplier by the costs anticipated for each industry sector. The difficulty with this approach is in transforming the data from an lump sum engineering cost estimate into the 80 industry classifications. The procedure used in this economic impact analysis was to assume that the individual multipliers are normally distributed. The mean multiplier for employment, income, and output was calculated for each

region and multiplied by the initial costs. The product is the change in employment, income, and output. Given a sample size of 80 sectors that are normally distributed, the sample size is large enough to approximate a standard normal distribution.

The advantage in using individual multipliers is their ability to trace impacts on the economic variables through individual industrial sectors. However, because the objective of this analysis was to look at marginal changes in total employment, income, and output—not at the changes in specific industrial sectors—such a detailed analysis was considered unwarranted.

The employment, income, and output multipliers for each region were then applied to the initial waste management project costs for each site under each waste-type alternative. As discussed above, the cost data were broken out into construction, operations, and transportation phases. When changes in employment and income were calculated for each waste-type alternative, they were weighted by the number of years involved for construction and operations activities. The percent change in employment and income is equal to the total time-weighted dollar change in the variable divided by the 1990 value of the variable, multiplied by 100.

The National-level impacts of waste management activities were calculated by using the National RIMS II multipliers. These impacts help to account for the leakage in expenditures that would occur at the regional level when purchases of goods and services must be made outside a particular ROI due to the inability of the regional economy to provide those goods or services. For example, steel is manufactured only in certain parts of the U.S. When steel is required by a site that is in an ROI that does not have a steel plant, the steel must be brought in from outside of the ROI. This purchase causes money "leakage" out of that ROI to somewhere else in the National economy. The National economy analysis is thus able to "capture" economic activity that is otherwise lost to the individual site ROIs.

Since the transportation expenditures would be made throughout the country, the National multipliers were also used to determine the impacts of transportation expenditures.

The next step was to multiply the respective grand mean multipliers for employment, income, and output respectively by the initial expenditure anticipated for each site and waste type alternative. The product of the initial cost and the multipliers gave the estimated change in personal income, job-years, and output.

C.4.5.3.2 *Analysis Assumptions*

This section identifies the assumptions used in developing the baseline conditions and impacts for the various waste types.

C.4.5.3.3 *Multiplier Analysis*

Baseline conditions for the impacts analysis used a two-tier ROI. The first tier included the 17 sites that contain the vast majority of DOE waste. A detailed ROI was developed based on the residence patterns of the site employees. Counties were included if they contained 5% or more of the site employees, until the counties selected accounted for 90% or more of the site employees. Contiguous counties were included by exception if there was reason to believe that excluding them might preclude a site-specific determination of where on a site a waste management facility could be located.

The second ROI tier included 37 sites that are anticipated to have relatively low expenditures, irrespective of the waste type or the Alternative. In most cases the second tier sites were waste donor sites. Since these sites will experience small impacts (due to little or no planned activity) they were not given the extensive treatment that the major sites received. The ROIs for each second tier site consists of the host and contiguous counties only.

As indicated above, multipliers were assembled for each of the ROIs associated with each site. The simplifying assumption regarding these multipliers holds that the average (mean) multiplier is an unbiased and efficient estimator of the any of the 80 multipliers.

Each waste type was analyzed using specific timing assumptions. Further, the HLW analysis used different timing assumptions for each alternative. The time frames identified in Table C.4–20 and employed in the analysis should be viewed as representative. Representative time cycles are used to show what would happen if a similar cycle were actually used. The time frame is required to annualize the changes in income and employment both to provide the absolute change in the variable and the percent change over the 1990 baseline. The time frames are proxies for any time period and are not intended to imply that a particular time frame has been selected.

Table C.4–20. Duration in Years of WM Activity Phases Assumed for Waste Type Economic Analysis

Waste Type	Construction Phase[a]	Operations Phase	Transportation
LLMW	4	15 (No Action = 25)	10 (No Action = 20)
LLW	4	15 (No Action = 25)	10 (No Action = 20)
TRUW	4	15 (No Action = 25)	10 (No Action = 20)
HLW	3	17 to 43[b]	34
HW	4	12	10

[a] Assumes 4 years of actual construction activity within a 10-year time frame to plan and implement facility construction.
[b] Varies with site and alternative.

In addition, it was assumed that an additional five years will elapse before the full economic impacts of any given or phase of the operation will occur. The time frame used to calculate impacts then includes the time over which the action is planned to occur plus five years.

The economic impact analysis was based on standard Keynesian economic theory. This theory holds that aggregate demand is a function of income. When income is generated in the form of a wage, several deductions are made reducing the amount of money that is available for respending. These deductions are given in Table C.4–21.

A coefficient of variance was calculated for the grand mean multipliers of the ROIs for the 47 sites. The coefficient of variance is equal to the standard deviation of the grand mean multiplier divided by the grand mean multiplier.

The grand mean multipliers and the multipliers' coefficient of variance for the 47 ROIs are reported in Table C.4–22 and Table C.4–23, respectively.

Table C.4-21. Wage Deductions Used in the Income Multiplier Analysis

Deduction	Percentage of Deduction
Federal income tax	18.0
Social security tax	7.6
State unemployment tax	1.5
Benefits (health and life insurance)	2.0
Personal savings	5.0
Total unavailable for respending	34.1
Total available for respending	65.9

C.4.5.3.4 *Limitations of the Multiplier Analysis*

The use of the input-output (I-O) system for estimating multipliers has several limitations, including:

- No explicit recognition of prices. Relative prices between industries change, and the prices are not updated. The most complete table in use today uses 1987 prices; price adjustments are made uniformly and do not capture changes in relative prices within an industry.
- Linear homogeneous production function. If any scale economies or diseconomies exist, they are not captured; expansion of one industry will not have the impacts on downstream industries that the I-O model assumes.
- Constant I-O formation ignores the possibility that capacity will be reached with the effect of changing relative prices and input substitutions.

While these limitations are important, the use of the multipliers is to show relative changes, i.e., what would happen if you did a similar thing in different places. While the limitations prevent the determination of the absolute changes in the magnitude of the economic variables, they are instrumental in identifying relative changes.

Table C.4-22. Grand Mean Multipliers

Site	Output (1)	Earnings (2)	Employment (3)
Ames	1.8968398	0.2686351	26.1
ANL-E	1.8992364	0.2794387	24.1
BCL	2.0945444	0.2963150	27.2
Bettis	2.0854729	0.2955736	26.8
BNL	1.8928028	0.2825461	24.9
Charleston	1.8486995	0.2632758	24.2
Colonie	1.9521110	0.2755395	26.0
ETEC	2.0860979	0.2918617	26.9
Fermi	2.1277356	0.3000036	27.1
FEMP	2.0115936	0.2992522	26.2
GA	1.9761869	0.2793827	26.2
GE	1.8819248	0.2698297	26.0
GJPO	1.8788433	0.2628304	25.5
Hanford	1.7345193	0.2606101	24.4
INEL	1.6539740	0.2501210	23.2
KCP	2.0661073	0.2920600	26.9
KAPL-K	1.6542548	0.2492809	22.1
KAPL-N	1.8803463	0.2665589	25.2
KAPL-W	2.0211218	0.2872877	26.0
LEHR	1.8814520	0.2667942	25.2
LBL	2.1162016	0.3093407	26.8
LLNL	2.1480631	0.3114184	28.2
LANL	1.7278235	0.2566492	23.6
Mare Is	2.0097511	0.2841494	26.5
Middlesex	2.0560625	0.2908983	26.2
Mound	1.7815385	0.2537604	23.7
NTS	1.7526830	0.2633199	23.4
Norfolk	1.7882339	0.2551058	23.9
ORR	2.0175825	0.3014903	26.7
PGDP	1.7091768	0.2612092	23.9
Palos	2.1394955	0.3019226	27.2
Pantex	1.8058253	0.2664281	24.8
Pearl H	1.8166110	0.2560974	24.3
Pinellas	1.9382666	0.2750944	25.8
PORTS	1.7395320	0.2644895	24.8
Ports Nav	2.0104574	0.2857046	26.3
PPPL	2.0962324	0.2967151	26.8
Puget So	1.9194054	0.2736098	25.3
RMI	1.8073449	0.2559203	23.4
RFETS	1.9088693	0.2832914	25.2
SNL/NM	1.8358633	0.2730185	24.9
SRS	1.8961558	0.2789010	25.8
SLAC	1.7502934	0.2507150	23.3
UMo	1.7537006	0.2497958	24.0
WIPP	1.7094931	0.2559931	23.7
WSSR	2.1302335	0.3014761	27.3
WVDP	2.1326031	0.3170268	27.8
National	3.0829564	0.8324667	36.8

Table C.4–23. Multipliers' Coefficient of Variance[a]

Site	Output	Earnings	Employment
Ames	0.1282514	0.3232824	0.7017540
ANL-E	0.1514593	0.4842782	0.6223096
BCL	0.1335457	0.3108199	0.5816449
Bettis	0.1423880	0.3197699	0.5657588
BNL	0.1076392	0.4656121	0.6015071
Charleston	0.1350718	0.3236767	0.6538367
Colonie	0.1183233	0.3023482	0.6448926
ETEC	0.1194562	0.3069452	0.5785328
Fermi	0.1395721	0.3117937	0.5540122
FEMP	0.1212080	0.4434402	0.5735707
GA	0.1184384	0.3187351	0.6262334
GE	0.1310743	0.3253468	0.7018351
GJPO	0.1458825	0.3387602	0.7130032
Hanford	0.1291553	0.4987933	0.7501411
INEL	0.1174174	0.5183568	0.7851976
KCP	0.1249323	0.3062415	0.5880993
KAPL-K	0.1055506	0.5082354	0.6985579
KAPL-N	0.1108195	0.3142466	0.6520623
KAPL-W	0.1330296	0.3176867	0.5789079
LEHR	0.1195645	0.3213139	0.6552262
LBL	0.1336941	0.4379207	0.5548303
LLNL	0.1299192	0.4302718	0.6280589
LANL	0.1234926	0.5115640	0.7293250
Mare Is	0.1336816	0.3163528	0.6208246
Middlesex	0.1337611	0.3137265	0.5703249
Mound	0.1183593	0.3377189	0.7091450
NTS	0.1305871	0.5074167	0.6517835
Norfolk	0.1225205	0.3380128	0.6498472
ORR	0.1279087	0.4467180	0.5916954
PGDP	0.1297143	0.5055180	0.7517458
Palos	0.1399090	0.3116253	0.5491915
Pantex	0.1236165	0.4922549	0.7415270
Pearl H	0.1267270	0.3324984	0.6697828
Pinellas	0.1146860	0.3179148	0.6247028
PORTS	0.1408416	0.5007350	0.7359551
Ports Nav	0.1414415	0.3262595	0.5881818
PPPL	0.1343447	0.3116302	0.5635358
Puget So	0.1342005	0.3296160	0.6086124
RMI	0.1327751	0.3383731	0.6790840
RFETS	0.1261521	0.4754906	0.6146155
SNL/NM	0.1197497	0.4900238	0.6760818
SRS	0.1370186	0.4650688	0.7017991
SLAC	0.1079955	0.3308188	0.6862206
U of Mo	0.1305158	0.3448562	0.7495700
WIPP	0.1205319	0.5070867	0.7579089
WSSR	0.1401402	0.3130342	0.5595690
WVDP	0.1362926	0.4282287	0.5648346
National	0.1816865	0.2830192	0.3542612

[a] The coefficient of variance is equal to the standard deviation of the mean multiplier divided by the mean.

C.4.5.3.5 *Analysis Data*

Most of the baseline data used in this analysis are from the Bureau of Economic Analysis whose "Regional Economic Information System" provides historical data on employment and personal income.

The cost figures used in the analysis include the fully loaded costs of setting up a business to build and operate the WM facilities. They also include a set of linear scaler modules that can be assembled on the basis of the type of waste and waste volume. The modules can be placed in any part of the country and either scaled to accommodate the volume of waste, or adjusted in terms of the number of operating years to accommodate different waste volumes. The cost figures include a 30% contingency.

C.4.5.3.6 *Evaluation Techniques*

The economic model outputs included changes in income, output, and job-years. When the timing assumptions were applied, the job-years variable was divided by the number of years to give the number of direct, indirect, and induced jobs in an ROI. All of the ROIs that were evaluated are anticipated to experience an increase in expenditures resulting in increases in employment, income, and output; therefore, all impacts are expected to be positive.

The primary evaluation technique is to identify the magnitude of the change. All of the impact categories are first measured in absolute terms. Then, income and employment inputs are calculated with respect to changes in the baseline income and employment.

C.4.5.3.7 *Presentation of Results*

Data from the analysis are presented in several places in the WM PEIS document. Chapter 4 provides affected environment data for the 17 major sites in text and tables. The additional sites are presented in the *Technical Report on Affected Environment for the DOE Sites Considered in the DOE Waste Management Programmatic Environmental Impact Statement* (DOE, 1995b). Chapters 6 through 10 present the results of the impacts analysis for each of the waste types and for each alternative. The primary variable in these chapters is the percent change in the number of jobs. Changes in personal income are also presented. Both

variables are presented in terms of absolute numbers as well as percent changes over the 1990 baseline. A 1% change in the number of jobs is considered a substantial positive benefit to the regional or National economy.

C.4.6 POPULATION IMPACTS

The analysis examined the potential for the waste management alternatives to cause the types of impacts that could result when any large industrial or public works project attracts workers and their families to an area.

C.4.6.1 Regions of Influence

The ROI included the geographic area surrounding the site that would be subject to the changes traditionally associated with large-scale industrial projects (such as changes in employment and demographics). The site-level ROI was defined, as an aggregate of whole counties to include the host county (or counties), any contiguous counties, and other counties within the region that contain at least 5% of the total site workforce (both DOE and contractor personnel). Where these counties did not represent at least 90% of the total site workforce, counties with progressively lower percentages were included until the 90% threshold was met.

The site ROI population was assumed to represent the affected community at each site. It was considered reasonable to expect that the effects of in-migration to a region would be experienced in existing, nearby communities that have the infrastructure and established community support networks necessary for social life.

The analysis quantified population changes that constitute or that may in turn cause a number of related changes in community characteristics and that are likely to affect community services and resources. The likelihood of these latter effects is inferred from the size of the expected temporary and permanent population changes during the construction and operations phases of the waste management projects and the general characteristics of the communities at each site.

C.4.6.1.1 *Potential Impacts of WM Project Labor Requirements*

Population increases and settlement patterns associated with worker in-migration to the ROI are the source of most social effects of the construction and operation of an industrial project. (Halstead et al., 1984; Canter, 1977). Sources of change include the introduction of new people into a region in response to new employment; loss of residents in response to a perceived diminished quality of life or loss of employment opportunities; or retention of residents, who might otherwise have left the area, as a result of improvement or enhancement of some social factor.

The construction and operation of waste management facilities can be expected to have some influence on the growth of the population in the regions surrounding the sites. This growth will raise important concerns based on the potential for changes to certain community characteristics such as size, diversity, stability, and the ability to provide necessary or locally desirable social services. Though the description of the precise nature and detail of these changes is dependent on site specific information regarding the location of any proposed facility, the size and characteristics of the inmigrating workforces and the number of existing site personnel actually employed on the project, some preliminary estimates can be made on the basis of the more general information available at the programmatic level.

C.4.6.1.1.1 Community Characteristics—Size, Diversity, Stability

Conventional effects associated with large industrial facilities include: the economic effects of increased local employment, the demographic effects of increased population growth, the fiscal effects of increased demands for social services, and social effects of perceived changes in the quality of life (Finley, 1983). These changes will usually result in other changes in community life. The temporary in-migration of construction workers and their families and the more permanent settlement of workers during the operations phase of the proposed action are relevant to this analysis.

The central impetus for change rests in the differences, both real and perceived, between the incoming population and those who already reside in the ROI. Important demographic characteristics that could change include age, sex, ethnic and racial composition, and income distribution. Potential disruptions to settlement patterns and relocation of local population are also important (Canter, 1993). Consequential

changes in the patterns of interaction of local residents also can be anticipated (Gramling and Freudenburg, 1992).

Other associated changes include: the level of diversity and complexity—affected when the number and types of social groups in the community are increased; and community cohesion—potentially affected by anything that decreases the desirability of the community itself or the desirability of associating or identifying with the community (Finsterbusch, 1980).

C.4.6.1.1.2 Community Services and Resources

Local community resources and especially the provision of services (health, education, and public safety services) to community residents are susceptible to any change in the size and composition of the local population (Canter, 1993). Along with community social and welfare services, these social services constitute primary resources to the populations of the affected communities. The mechanisms for providing these services can be disrupted by population growth or change in composition or location of the population. Other social resources, such as available housing and recreational and cultural resources, may also be affected by temporary or long-term in-migration. Project related growth is expected to increase demands for services provided by local and State governments in the affected regions.

Although it is not feasible to collect data on the capabilities of individual community service delivery systems without specific information regarding the physical location of the designated facility and the corresponding distribution of new population in the ROI, some qualitative prediction of impacts can be made on the basis of general population estimates. Impacts to social services and resources can be inferred from the direct and indirect labor requirements and associated changes in population size and mix anticipated for each of the alternatives. Impacts may be predicted on the basis of the potential for altering service provider to recipient ratios, such as student/teacher or doctor/patient ratios; decreased availability of facilities such as hospital beds or schoolroom seats; or the loss of services to segments of the community as a result of overcrowding or population relocation. A sudden need to provide resources to expand services or an increased capability to provide resources based on an increased population would cause fiscal impacts.

C.4.6.1.2 *Method of Population Analysis*

Because the factors that influence in-migration are multiple and complex, it was impossible to precisely predict the number of in-migrants at each site for the proposed alternatives. However, an estimate was made for each site based on total waste management project workforce requirements. Although this number is not a specific prediction of the actual in-migration into a site's ROI, it provides a basis for comparing potential changes in population across alternatives.

This analysis considered three types of in-migration associated with new requirements for (1) direct construction labor; (2) O&M labor; and (3) secondary labor resulting from new employment at the sites. The level of in-migration would be indirectly influenced by several factors: the current level of unemployment in the region; the economic conditions and the demands for labor (both within the region and in adjacent areas); the ability of the local workforce to provide the necessary skills; the presence and success of worker retraining programs; characteristics of workers and their families; and individual preferences for location and type of residence. The location and the personnel requirements of contractors who work on the project would also be factors; some may already be located in the region with available staff to meet the work requirement, while others may be located outside the region.

Other factors that would influence in-migration include the size of the project and proximity of the region to urban centers. Indirect employment and induced employment (additional employment in the region that is not directly connected to the project but results from increased expenditures in the region) would also contribute to changes in the resident population and to the general social character of the region.

This approach assumed that the following factors remain constant for all alternatives: worker family characteristics, residential locations, composition of the local workforce, and labor shortages among specific occupational groups in the region. No attempt was made to estimate the potential for in-migration that exceeds the number of jobs provided; only estimates of actual employment, direct and multiplier-based, are used. Estimates of peak employment or singular shortages of particular labor categories at particular sites are not included. The success rates of retraining programs at individual sites may affect the availability of labor, but this factor cannot be correctly appraised for this assessment.

The potential for the cumulative effect of this action and the other planned or foreseeable projects at the site to cause a rapid increase in population migration to the region of influence is a serious consideration for

the analysis of site-level impacts. The assessment of population impacts is therefore based on a conservative approach intended to highlight those actions and alternatives that could cause a rapid-change effect. This is especially important during the construction phase when peak periods for many projects may cause a sudden sharp increase in temporary employment at the site. Because the actual timing of future peak employment periods is not known, only a very general discussion is possible at the programmatic level. However, peak-period employment is provided in *Waste Management Environmental and Socioeconomic Impacts Methods and Results* (DOE, 1996a) as a guide to later site-specific analyses.

The actual number of in-migrants during any phase of the waste management project could not be precisely determined, but the literature provides some base assumptions and empirical data that were used in developing percentage estimators for the WM project phases based on the phases of similar projects:

- The percentage of construction jobs filled by in-migrants would be expected to range from 30 to 60% (Halstead et al., 1984). The actual figures for specific projects vary according to the following factors:
  - Size of the project
  - Proximity to urban centers
  - Local labor force
  - Requirement for specialized skills and crafts
  - Table C.4–24 lists the percentages for each of the 17 major sites based on the characteristics of the site ROI
- Job duration during the construction phase was assumed to be approximately four years, and most (85%) of in-migrant construction workers who are directly related to the project are phased out after this period.
- Local workers occupy 40 to 60% of new O&M jobs. Training or retraining programs may encourage local hiring. Because DOE has plans for a retraining program, it is assumed that no fewer than 40% of the available jobs will go to retrainees, 30% will go to other local workers, and 30% will go to in-migrants.
- Of all induced labor associated with the project, 50% will be hired from the local workforce.

For the quantitative estimate of population in-migration and associated characteristics, impacts are presented in the waste-type chapters for those sites where ROI population increases (including new workers and their families) were estimated to be 1% or greater than the 1990 population. This criterion assumes a minimum 1% surplus capacity in public service delivery systems, infrastructure, and other health and welfare services. An increase of less than 1% would also not normally be expected to change the general

Table C.4-24. Percentage of Construction Workers Expected to In-Migrate to Each of the 17 Major DOE Sites

Percentage	Sites
30	BNL
40	ANL-E, FEMP, LLNL, ORR, RFETS, SNL/NM, WVDP
45	Hanford, NTS
60	INEL, LANL, PGDP, Pantex, PORTS, SRS, WIPP

distribution of demographic characteristics within the population as a whole (e.g., change the character of the population by changing the percentage of the population in a given category such as gender, marital status, etc.). These sites are assumed by the analysis to experience a greater potential for change to the social environment as a result of the proposed action. Additionally, sites with estimated population increases over one-half of 1% were assumed to have a potential for minor impacts to social characteristics and the provision of social services and are noted in the discussion where appropriate.

Because the precise location of new facilities at a site and the subsequent preferred residential location of in-migrating workers are not known, this assessment serves only as an estimate for the purpose of comparing impacts. Noticeable effects may occur at much lower levels than 1%, if in-migration is concentrated in one or two communities.

C.4.7 Environmental Justice Impacts

In accordance with the requirements of Executive Order 12898, DOE evaluated the potential for the WM PEIS program alternatives to cause disproportionately high and adverse human health or environmental effects on minority and low-income populations. DOE identified minority and low-income populations residing within 50 miles of the 17 major sites, then reviewed the human health effects and environmental impacts associated with alternatives for the five waste types at those sites. The review included potential impacts under each of the major scientific disciplines evaluated for the waste-type alternatives—human health risk, air quality, water resources, ecology, economics, population impacts, land use, infrastructure, and cultural resources impacts. Regarding health effects, normal facility operations were examined, with accident scenarios evaluated in terms of the risk to the public.

Environmental justice analysis for specific transportation routes was not done because specific routes were not analyzed in the transportation risk analyses. While a disproportionate share of minorities in the population resides near interstate highways and railroads, the major risks to the public from truck transportation are to travelers on the highways from the physical impact of accidents and routine exposure during rest stops. In both cases, on the interstate highways where these major risks would be incurred, the same minorities are found to be disproportionately lower in representation (DOT, 1992). Therefore, minorities are not expected to be receiving a disproportionately higher share of the truck transportation risks.

For rail shipments, the primary risks to the public are from radiological exposure during classification in railyards, primarily at the start and end of each shipment, and from emissions of diesel exhaust from trains in urban areas. Although adverse impacts could occur in the unlikely event of a high-consequence accident, any potential disproportionality with respect to any population—minority, low income and/or American Indian populations included—is subject to the randomness of the combination of factors that can produce such impacts.

C.4.7.1 Environmental Justice Overview

Environmental justice means the fair treatment of people of all races, cultures, and income levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (EPA, 1994a). Environmental justice impacts refer to adverse effects that result when one or more of a broad range of factors tends to place disproportionate adverse environmental impacts on minority (specifically including Native American) and low-income populations.

A Word About Equity and Economics

The environmental justice analyses presented in this document look only at risk and population characteristics near sites. The analyses do not attempt to weigh positive economic effects associated with increased treatment, storage, and/or disposal against associated risk.

C.4.7.1.1 *Issuance of the Executive Order on Environmental Justice*

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority and Low-Income Populations*, became effective when signed on February 11, 1994. The Executive Order requires all Federal agencies to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. The Executive Order also requires federal agencies to provide minority and low-income communities access to information and public participation in matters relating to environmental justice. Additionally, to the extent practicable and appropriate, agencies must examine consumption patterns of fish and wildlife where they may be affected by agency activities. Risks inherent in such consumption must be communicated to at-risk populations.

EPA has convened an interagency Federal Working Group on Environmental Justice to provide guidance to Federal agencies on criteria for identifying disproportionately high and adverse human health or environmental effects on minority and low-income populations, and to serve as an information clearinghouse, coordinate research and data collection, disseminate existing data and studies, provide public participation, organize interagency model projects, and deal with other environmental justice issues that require cooperation among Federal agencies. DOE is a member of the Working Group.

Under the Executive Order, agencies are required to develop agency-wide environmental justice strategies to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of the agency's programs, policies, and activities on minority and low-income populations. Using the strategy, the agency is required to conduct its programs, policies, and activities that "substantially affect human health or the environment" in a manner that insures that they do not subject persons (including populations) to discrimination.

Federal agencies are required to implement the Executive Order consistent with and "to the extent permitted by existing law." However, the Executive Order is intended only to improve the internal management of the Executive branch and does not create "any right, benefit, or trust responsibility, substantive or procedural, enforceable at law or equity by a party against the United States, its agencies, its officers, or any person." The Executive Order is not to be construed to create any right to judicial review involving the compliance or noncompliance of the United States, its agencies, its officers, or any other person. A memorandum for the heads of all departments and agencies, circulated with the Executive Order,

underscored the application of Title VI of the Civil Rights Act of 1964, NEPA, the Freedom of Information Act, the Sunshine Act, and the Emergency Planning and Community Right-to-Know Act as existing law particularly applicable to environmental justice (Office of the President, 1994).

"Minority and low-income populations" are not defined under the Executive Order. Consequently, U.S. Bureau of Census definitions, which appear in a variety of documents examining environmental justice impacts, were used. Generally, as defined by the U.S. Department of Commerce, Bureau of Census, minority populations include Black, American Indian, Asian-Pacific, and Hispanic racial and ethnic categories. Native American populations are specifically identified under the Order. Low-income populations are those whose income level is below the poverty level, also as defined by the Bureau of Census (DOC, 1992c,d). A more comprehensive definition of these two groups is presented in Section C.4.7.2.1.1.

C.4.7.1.2 *Status of Guidance on Environmental Justice*

Although the Working Group has not issued final guidance on the approach to be used in analyzing environmental justice, it has issued draft definitions of terms in the *Draft Guidance for Federal Agencies on Key Terms in Executive Order 12898*, dated November 28, 1994. These definitions, with slight modifications, were used in the PEIS environmental justice analysis. Further, in coordination with the Working Group, the Council on Environmental Quality issued Draft Guidance on May 24, 1996. DOE is also in the process of preparing internal guidance for the implementation of the Executive Order. Because both DOE and the Working Group are still in the process of developing final guidance, the approach used in this analysis might depart somewhat from whatever guidance is eventually issued.

C.4.7.2 Approach to WM PEIS Consideration of Environmental Justice Impacts

Any assessment of environmental justice concerns rests on an examination of the composition of the population potentially affected by a given project or action. The potential of a given project or action to unfairly or "disproportionally" affect one segment of the population can be measured, in part, by determining the proportion of the potentially affected population that is minority or low-income. Once minority and low-income proportions of an affected population are identified, any potential impact or

human health effect from a given project or action that is determined to be potentially adverse can be examined in the context of its likelihood to disproportionately affect one or both of these population groups.

For the environmental justice assessment, the following effects, based on definitions by the Working Group, were evaluated for alternatives under each of the five waste types:

- Disproportionately high and adverse human health effects—Any human health effect from exposure to environmental hazards that exceeds generally accepted levels of risk and affects minority and low-income populations at a rate that appreciably exceeds the rate for the general population. Adverse health effects are measured in risks and rates that could result in latent cancer fatalities, as well as other fatal or nonfatal adverse impacts to human health.
- Disproportionately high and adverse environmental impacts—A deleterious environmental impact determined to be unacceptable or above generally accepted norms. A disproportionately high impact refers to an environmental hazard with a risk or rate of exposure for a low-income or minority population that appreciably exceeds the risk or rate of exposure for the general population.

C.4.7.2.1 *Identification and Mapping of Minority and Low-Income Populations*

In order to determine the degree or existence of disproportionality, demographic information obtained from the U.S. Bureau of the Census was integrated into a geographic information system to identify minority and low-income populations residing in a zone of potential impact surrounding each of the sites under consideration. This zone was defined as a circle with a 50-mile radius, and whose center was either at the site center for the smaller DOE sites or at an existing waste management location for the six larger DOE sites (Hanford, INEL, LANL, NTS, ORR, and SRS). This 50-mile radius was selected because it was judged to encompass virtually all of the human health risks and environmental impacts that may occur. It was used to capture the offsite population at risk in the human health risk assessment of airborne dispersion of waste management facility emissions. It also encompasses the majority of communities that would be affected socioeconomically by waste management program actions.

C.4.7.2.1.1 Definitions

The following definitions were used to analyze the composition of populations residing around each site and to generate the maps presented in this appendix (see Figures C.4–7 through C.4–40, presented after Section C.4.7.2.3).

- A ***census tract*** is an area defined for the purpose of monitoring census data that is usually comprised of between 2,500 and 8,000 persons. When first delineated, census tracts are designed to be homogenous with respect to population characteristics, economic status, and living conditions. Census tracts do not cross county boundaries. The spatial size of census tracts varies widely depending on the density of settlement. Census tract boundaries are delineated with the intention of being maintained over a long period of time so that statistical comparisons can be made from census to census. For census tracts that were only partially inside the 50-mile radius, an even population distribution was assumed for the tract area and population was calculated as a proportion of the tract area inside the 50-mile radius (i.e., if 40% of the tract area was inside the 50-mile radius, 40% of the tract population was counted).
- A ***minority population*** is a group of people and/or community experiencing common conditions of exposure or impact that consists of persons classified by the U.S. Bureau of the Census as Negro/Black/African-American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, or other nonwhite, based on self-classification by the people according to the race with which they most closely identify. In order to avoid double-counting minority Hispanic persons (Hispanics can be of any race), only white Hispanics were included in the tabulation of racially based minorities. Nonwhite Hispanics had already been counted under their respective minority racial classifications (e.g., Black, American Indian). For purposes of this analysis, a minority population consists of any census tract within the 50-mile zone of impact with a minority population proportion greater than the national average of 24.4%.
- A ***low-income population*** consists of persons of low-income status. Low-income status is based on U.S. Census Bureau data definitions of individuals living below the poverty line. The poverty line is defined by a statistical threshold that considers family size and income. For 1990, the poverty line threshold for a family unit consisting of four individuals, based on 1989 income, was $12,674. For purposes of this analysis, a low-income population consists of any census tract within the 50-mile zone of impact at each site that has a low-income population proportion greater than the national average of 13.1%.

C.4.7.2.1.2 Mapping Procedures

For each of the 17 major WM sites, demographic maps were generated through a geographic information system that utilized 1990 census data available from the U.S. Bureau of the Census. Maps of the minority and low-income populations residing within 50 miles of the DOE sites are shown in Figures C.4–7 through C.4–40, which follow Section C.4.7.2.3. Federally recognized Native American tribal lands within 50 miles of each site were also identified and mapped and are included in this appendix (see Figures C.4–7 through C.4–23). These maps are based on 1990 U.S. Bureau of the Census Tiger Line files, which contain political boundaries and geographical features, and Summary Tape Files 1 and 3, which contain demographic information (DOC, 1992c,d). Data were resolved to the census tract group level.

C.4.7.2.2 *Review of High and Adverse Health Risks and Environmental Impacts*

The environmental justice analysis presented in each waste-type chapter is based on a review of the findings of the risk assessment for public health effects from proposed WM activities at each site and from transportation of wastes. If the PEIS human health risk assessment findings indicated that risks to the general population residing within 50 miles of each site would be low, then it was reasonable to conclude that no segment of the population would experience disproportionately high and adverse health risks, including any minority or low-income populations.

DOE has not evaluated the human health risk to subpopulations that may derive a portion of their food supply from native plants and animals that live near the DOE sites. The results of such a complex analysis would likely vary widely both within and among sites, depending on the assumptions used for such parameters as locations of waste management facilities on the sites, routes of exposure, and dietary habits. Thus, the results would not help to clarify the programmatic decision. The risk to human health for ingesting native plants and animals cannot be fully analyzed with confidence until the locations of facilities on the sites are known, the routes of exposure explicitly defined, and the dietary habits of affected subpopulations quantified. Therefore, analysis of health effects from subsistence consumption of fish, wildlife, and native plant species is not included in the WM PEIS but may be considered in sitewide or project-specific NEPA documents.

The analysis also reviewed environmental impacts, focusing on such effects as air quality, where adverse environmental effects could lead to adverse health effects. Once again, disproportionately high and adverse

impacts on minority or low-income groups would not be expected where the risks to the general population from environmental impacts would be low. Where risks or environmental impacts were found to be adverse, mitigation measures are described that could minimize impacts and thus eliminate the potential for disproportionately high impacts to any minority or low-income populations that might be affected.

C.4.7.2.3 *Analysis of Risk and Environmental Justice Impacts*

The following screening criteria, based on the WM PEIS risk analysis, were used to determine which WM sites would be analyzed for potential environmental justice concerns (generally over a 20-year operating period):

- A population risk greater than or equal to one latent cancer fatality from incident-free treatment facility operations
- A nonworker MEI cancer fatality probability of 1×10^{-6} or greater from incident-free treatment facility operations (*Risk Assessment Guidance for Superfund* [EPA, 1989])

If a WM site had projected health risks greater than or equal to the conditions described in either of the two screening criteria, regardless of waste type or WM program alternative, further analysis was justified. Conversely, an analysis of potential environmental justice impacts at a particular site was not warranted if health risks were projected to be lower than those described in both criteria. If a particular alternative did not generate health effects exceeding these screening criteria, no disproportionately high and adverse health effects would be expected. Consequently, no environmental justice impacts would be expected, even if the population surrounding a site had minority or low-income proportions greater than the national average.

For the analysis of potential environmental justice impacts from treatment facilities operations, screening (at least one latent cancer fatality) was used to identify sites and alternatives needing further analysis. For sites with projected health effects associated with a specific waste type exceeding the screening limits, a sector block analysis was conducted. A grid consisting of 16 pie-shaped sectors (see Figure C.4–7) positioned 360° around the centroid of a site and 10 concentric circles (with interval sizes of 1, 5, and 10 miles) radiating outward from the centroid to the outer edge of the ROI was used to break down the ROI into sectors and blocks. A block consisted of the portion of a sector bounded by (or located between) concentric circles. The WM PEIS risk analysis was used to derive a sector block dose value (or unit concentration), which was distributed to each tract within a sector block. For tracts that crossed sector block

boundaries, the dose value was weighted according to the fraction of the tract occupying the sector block. After a dose value was assigned to each tract, the tract was classified as either minority or not (or low-income or not). An examination of the tracts receiving the highest doses was conducted to determine the proportion of these tracts that were minority or low-income. If the proportion of minority or low-income tracts receiving higher doses was higher than the proportion of minority or low-income tracts in the general population, an environmental justice impact was declared. Two additional analytical steps were performed. The same analysis was performed using only the census tracts receiving the upper 10% of the dose. In addition, the statistical correlations for dose and percentage minority and low income were calculated for LANL, the only site meeting the selection criterion for population risk.

To determine whether impacts to a nonworker MEI at WM sites under the various waste type alternatives could be disproportionate, a screening criterion (a nonworker MEI cancer fatality probability of 1×10^{-6} or greater from incident-free operations) was used to identify sites requiring further analysis. Once these sites were identified, WM PEIS risk modeling was reviewed to locate the sector block containing the nonworker MEI for each selected site. A demographic analysis of the MEI sector block was then conducted to determine the composition of the census tract population. If the MEI sector block was composed of minority or low-income census tracts, a finding of potential for disproportionate health effects was included in the discussion of impacts for the relevant waste type and alternative. In most cases where more than one census tract was located in the MEI sector block, the tract located closest to the site was used to determine potential disproportionality. This approach was conservative and did not take credit for the possibility that, proportionately, the aggregate population of the MEI sector block may not exceed the national average for minority or low-income populations.

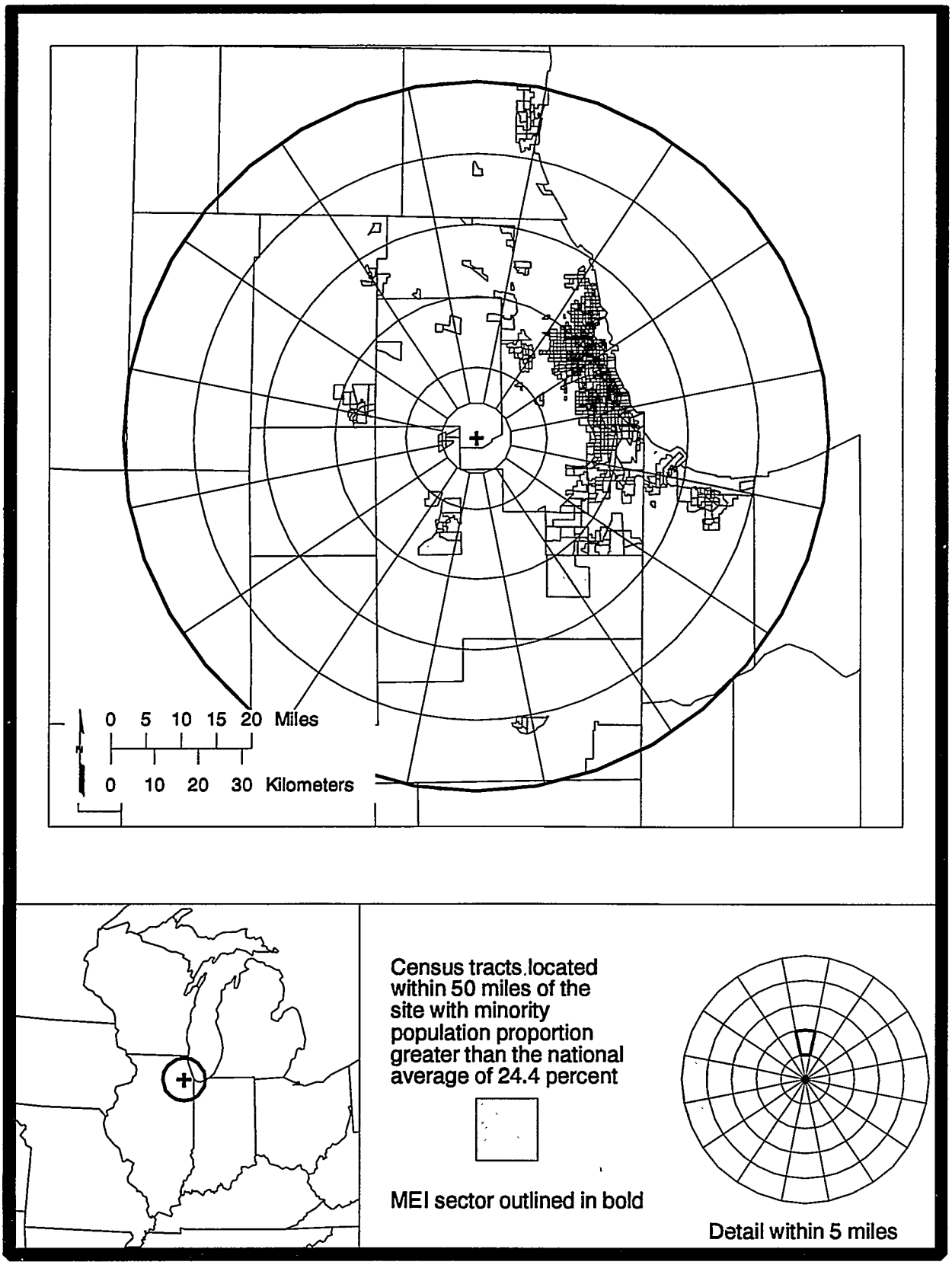


Figure C.4–7. Distribution of Minority Populations at Argonne National Laboratory-East.

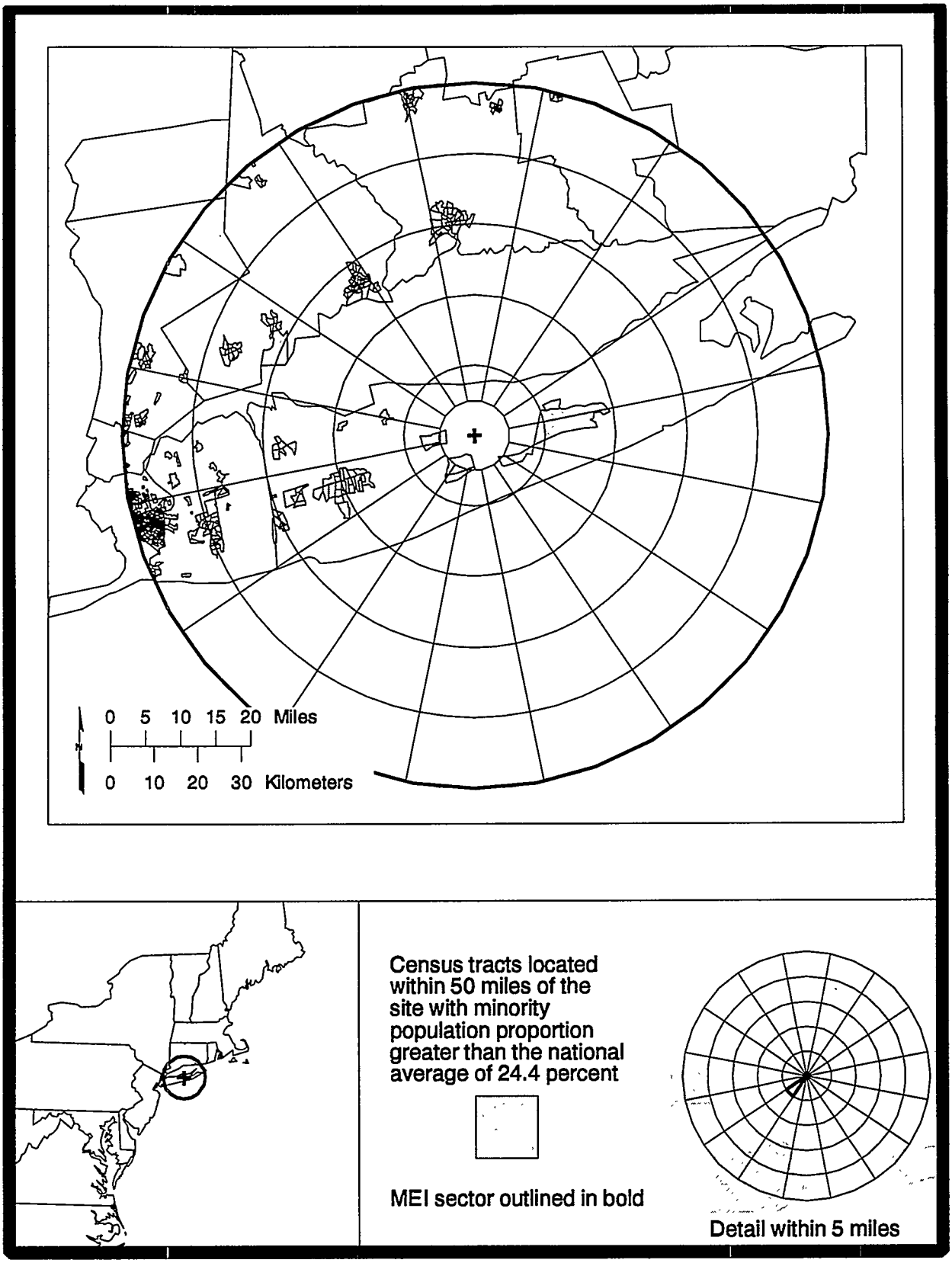


Figure C.4–8. Distribution of Minority Populations at Brookhaven National Laboratory.

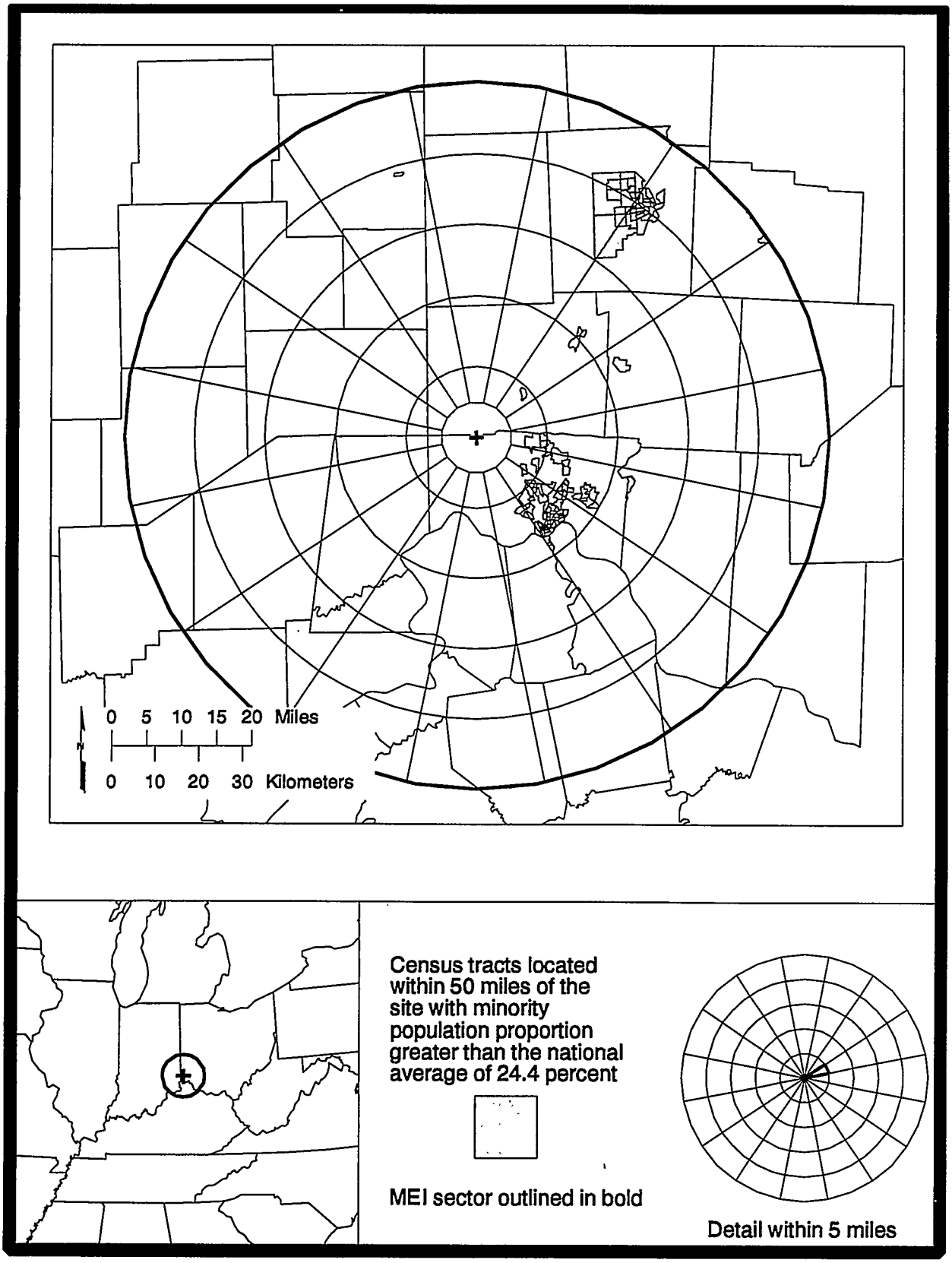


Figure C.4–9. Distribution of Minority Populations at Fernald Environmental Management Project.

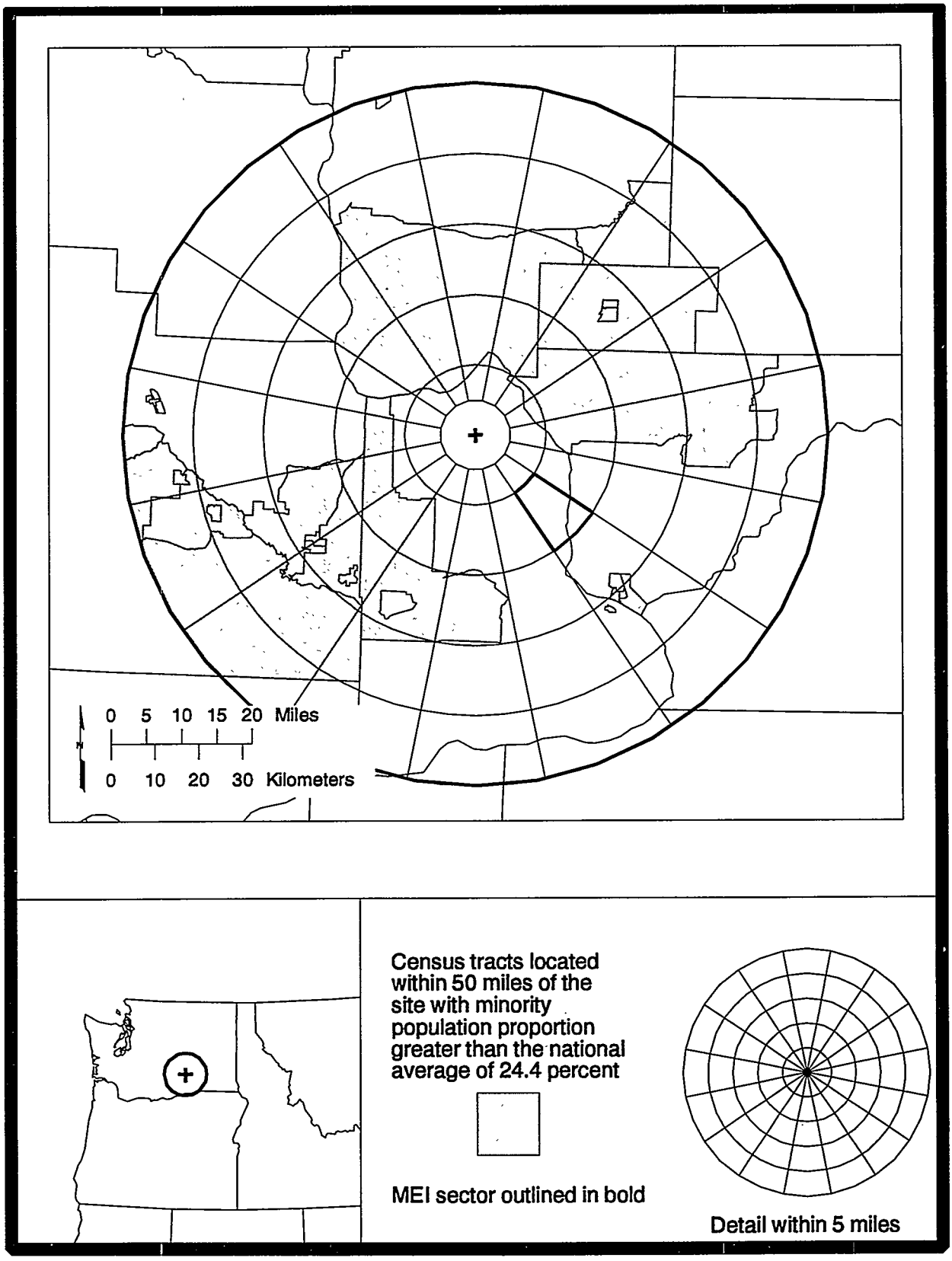


Figure C.4-10a. Distribution of Minority Populations at the Hanford Site.

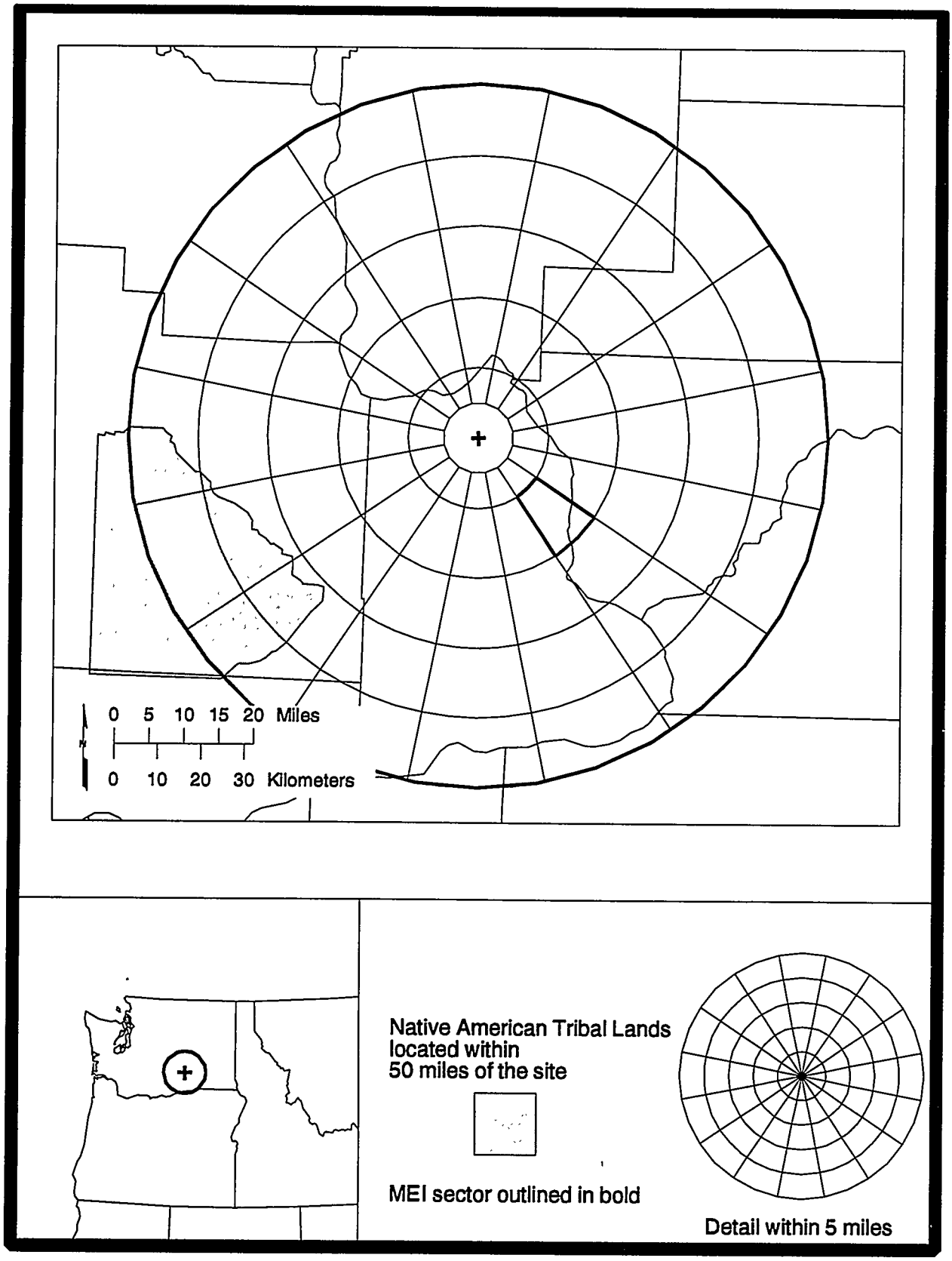


Figure C.4-10b. Location of Tribal Lands at the Hanford Site.

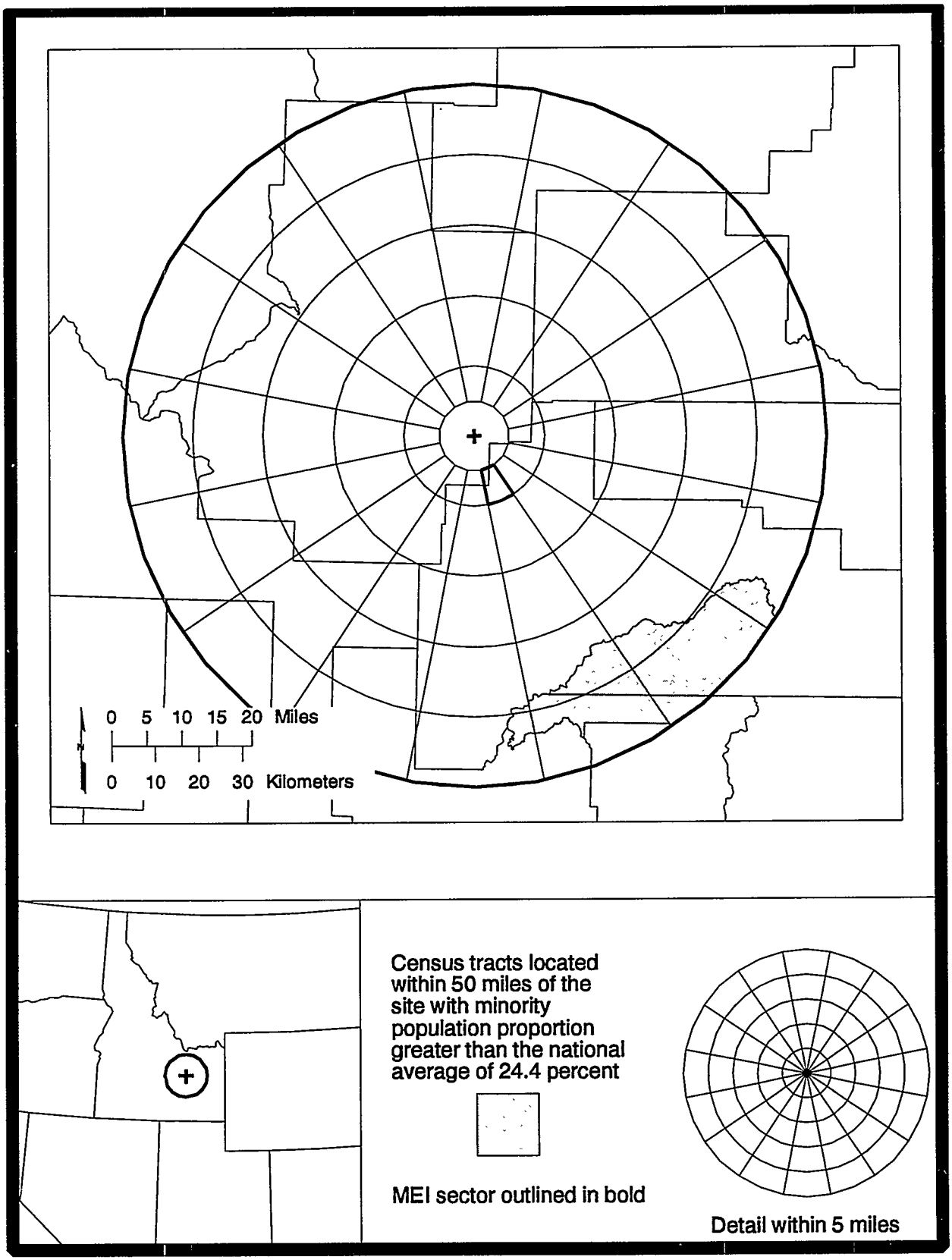


Figure C.4–11a. Distribution of Minority Populations at Idaho National Engineering Laboratory.

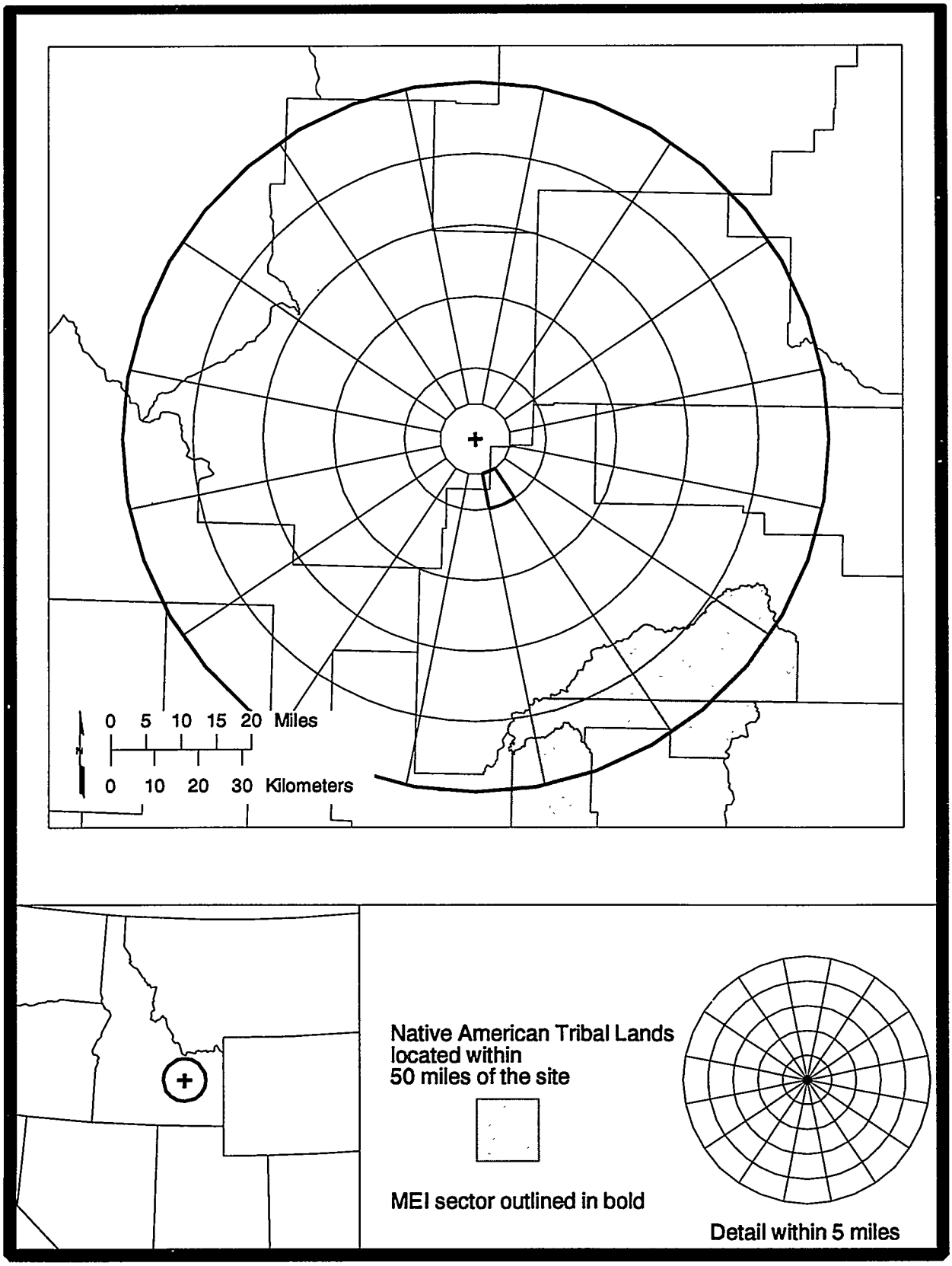


Figure C.4-11b. Location of Tribal Lands at Idaho National Engineering Laboratory.

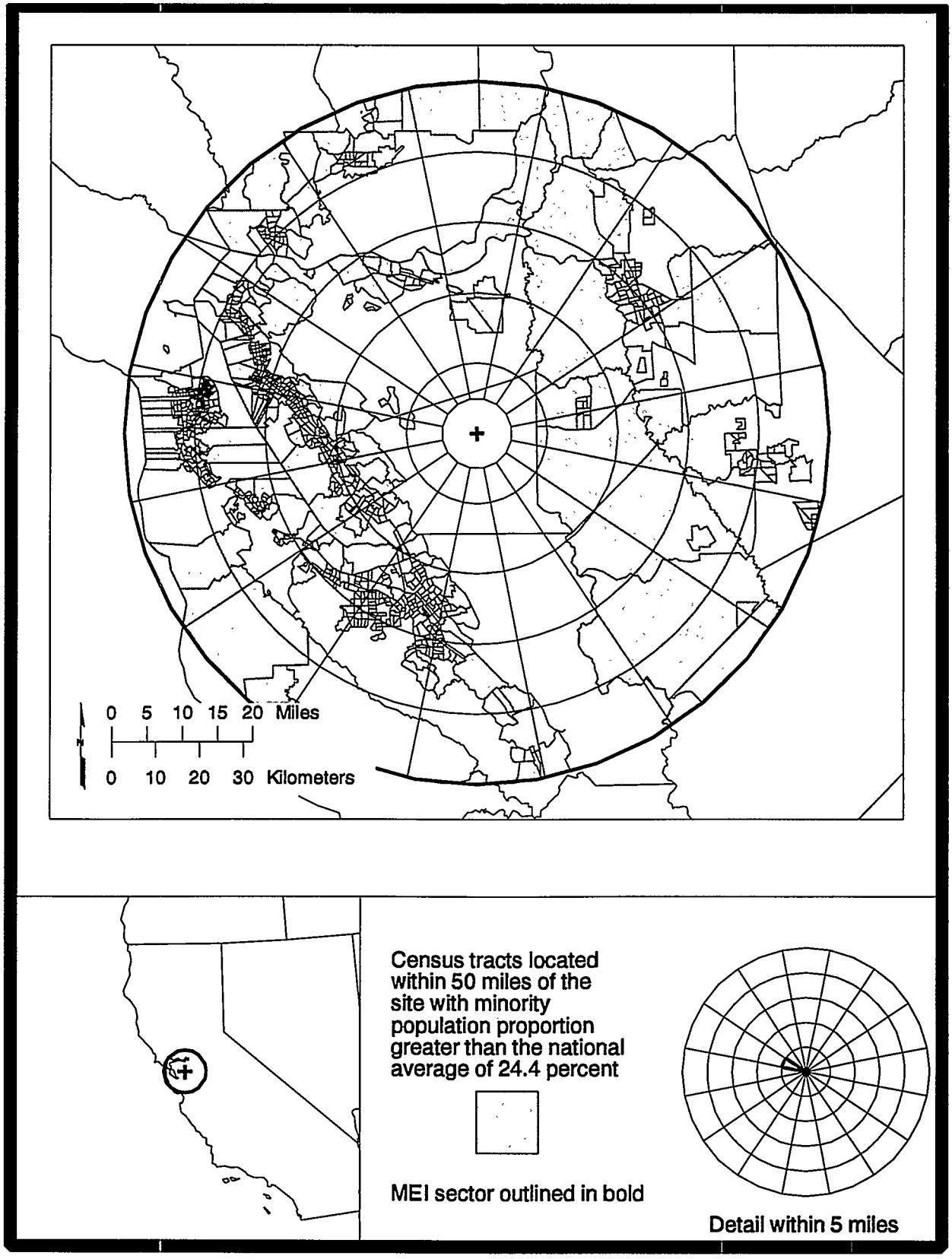


Figure C.4–12. Distribution of Minority Populations at Lawrence Livermore National Laboratory.

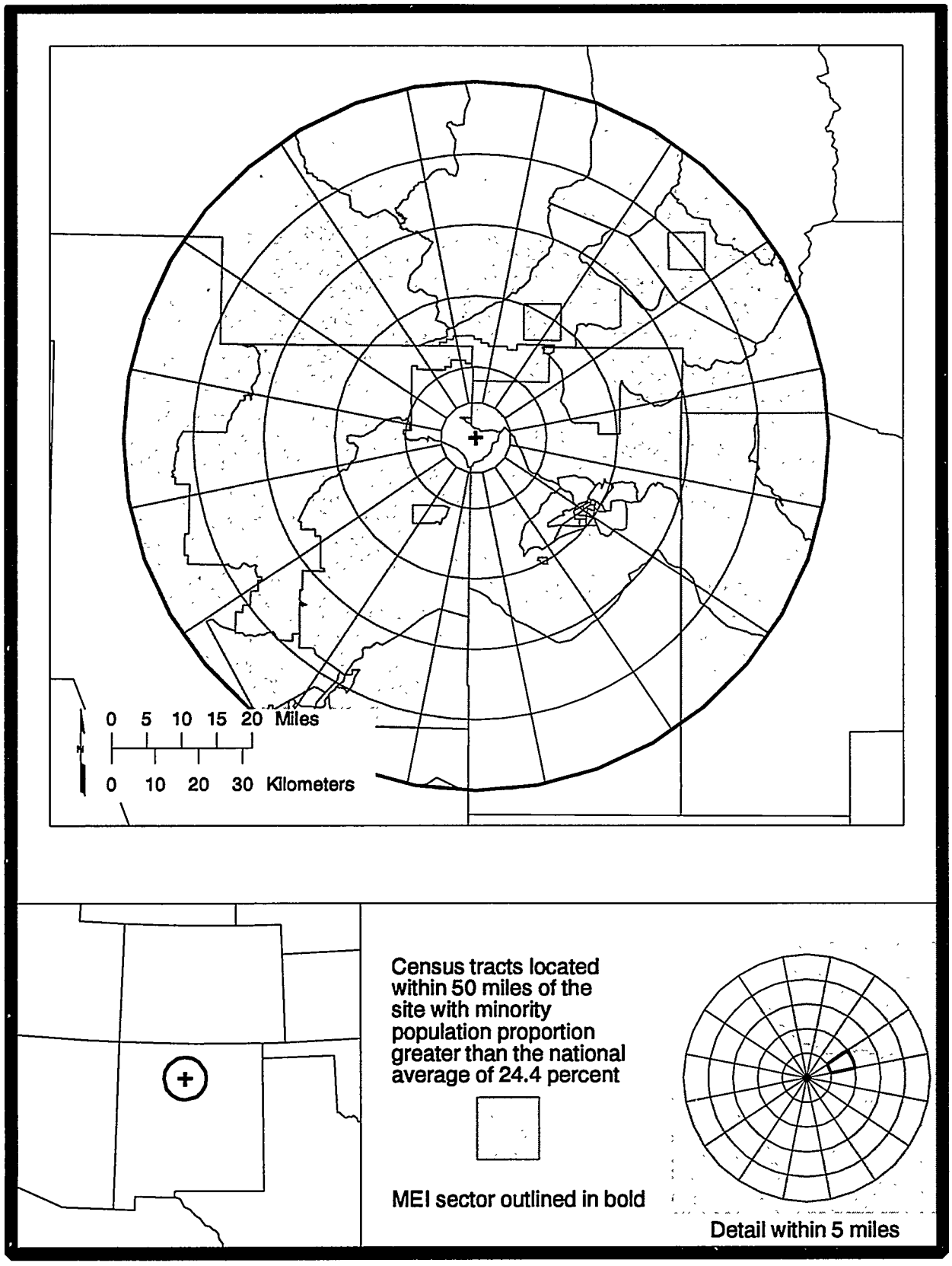


Figure C.4–13a. Distribution of Minority Populations at Los Alamos National Laboratory.

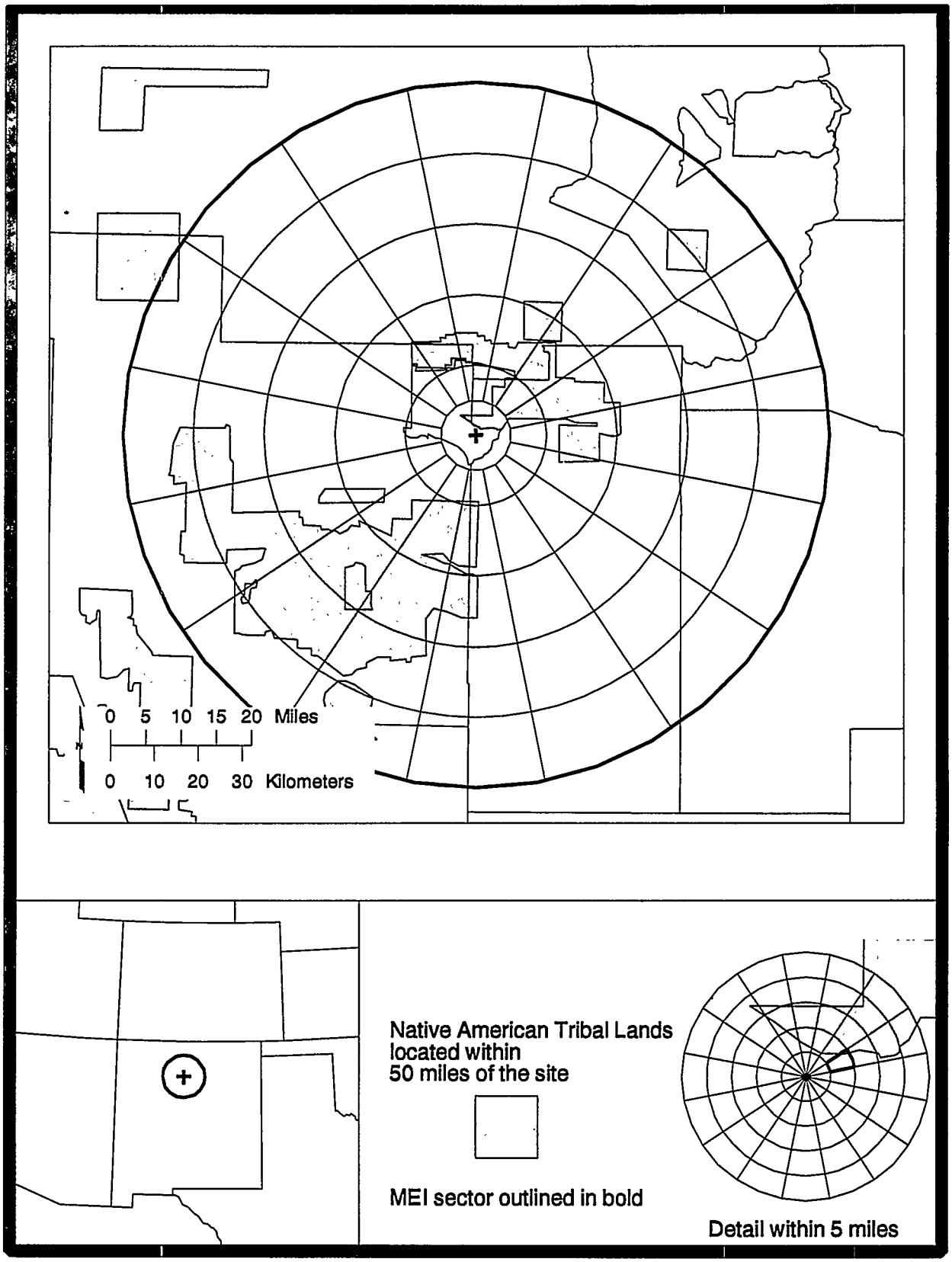


Figure C.4-13b. Locations of Tribal Lands at Los Alamos National Laboratory.

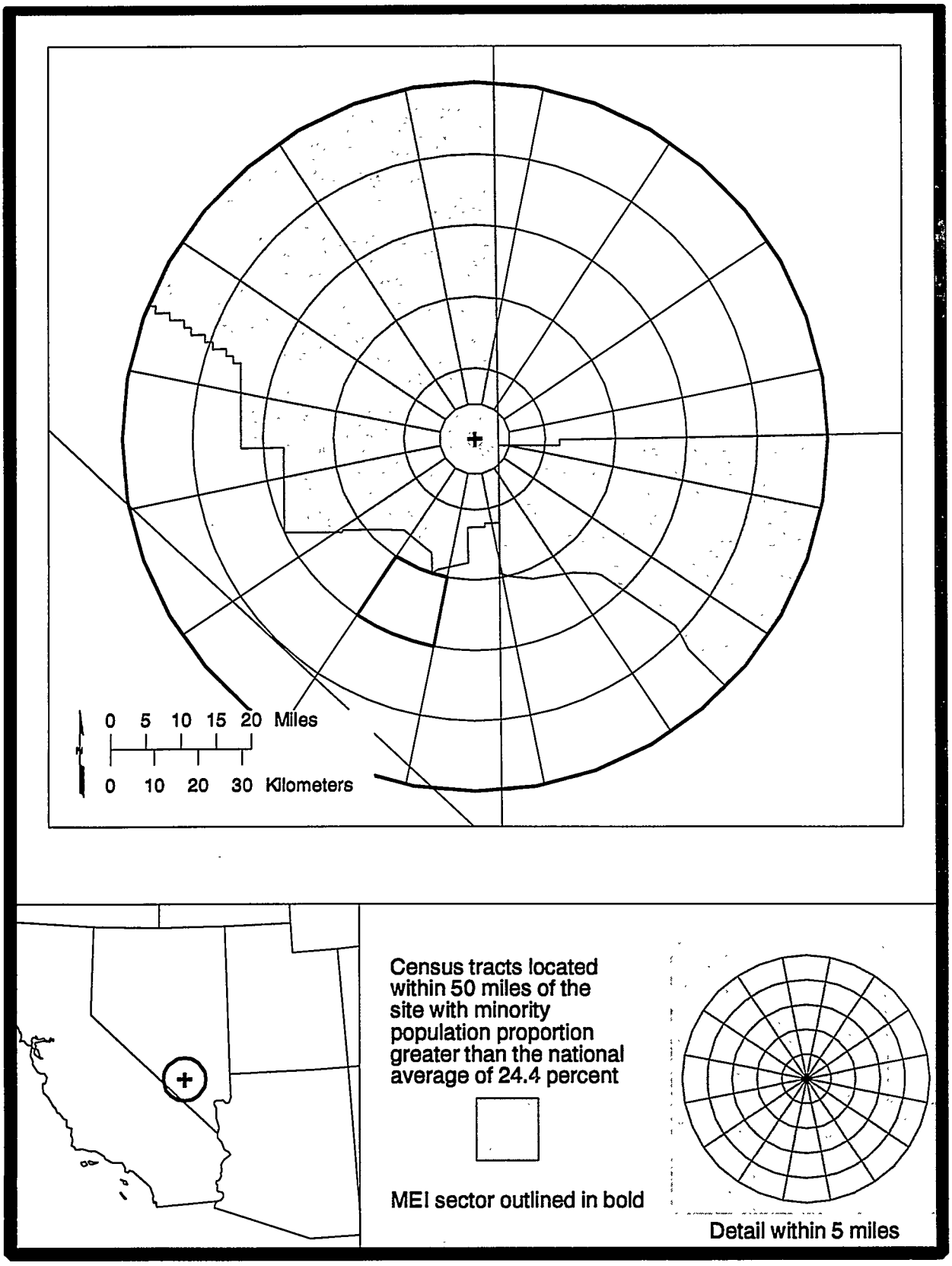


Figure C.4-14. Distribution of Minority Populations at the Nevada Test Site.

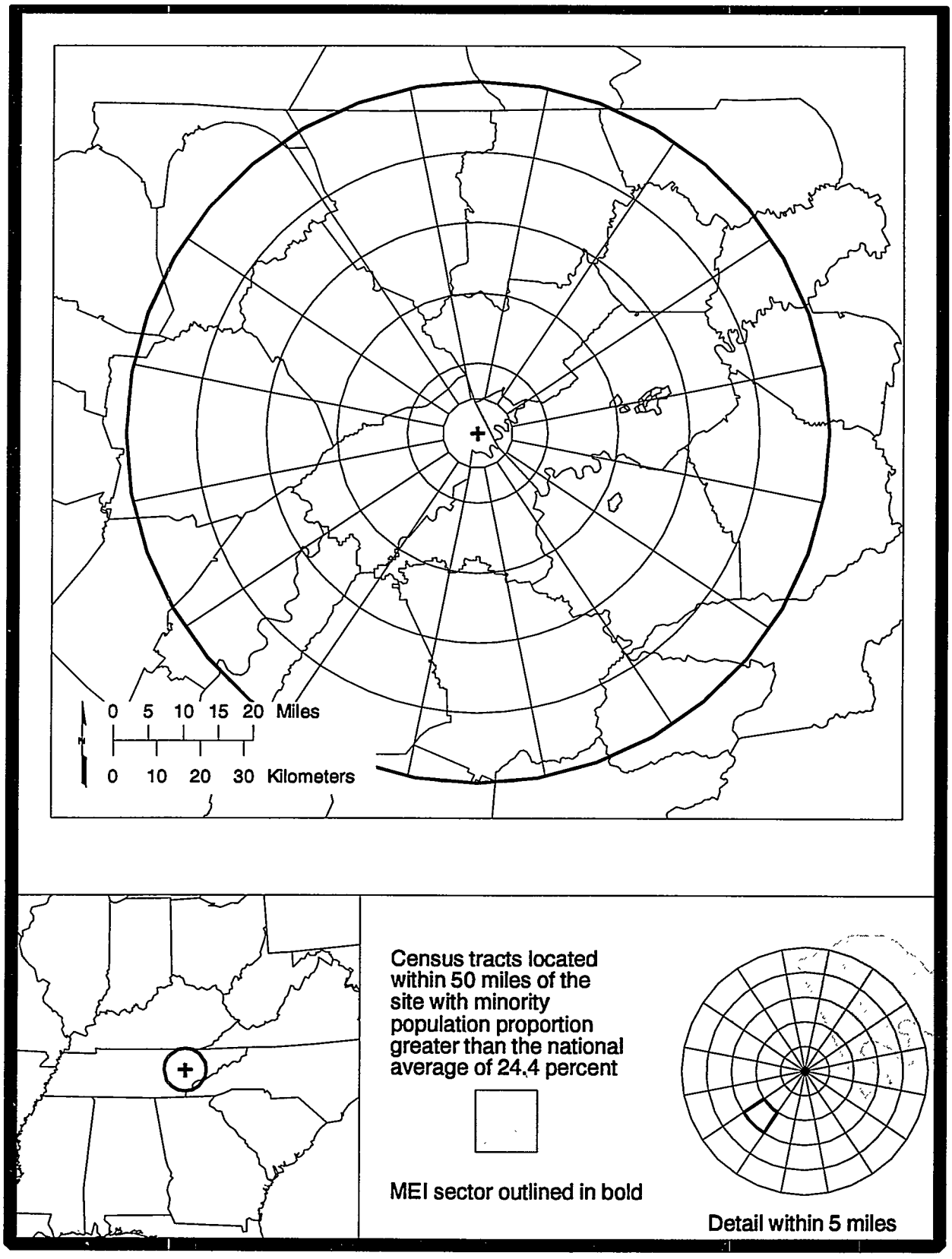


Figure C.4–15. Distribution of Minority Populations at the Oak Ridge Reservation.

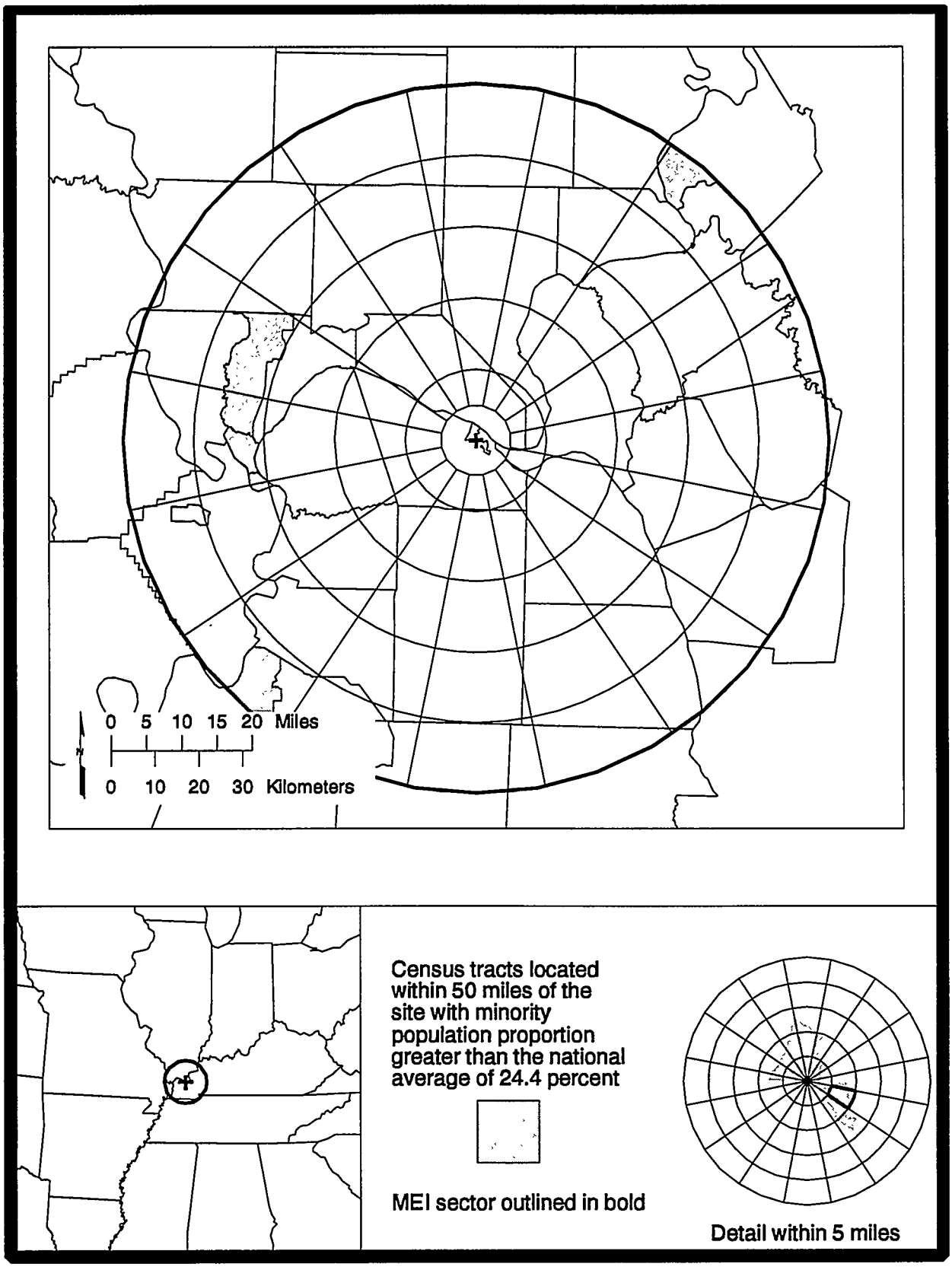


Figure C.4–16. Distribution of Minority Populations at the Paducah Gaseous Diffusion Plant.

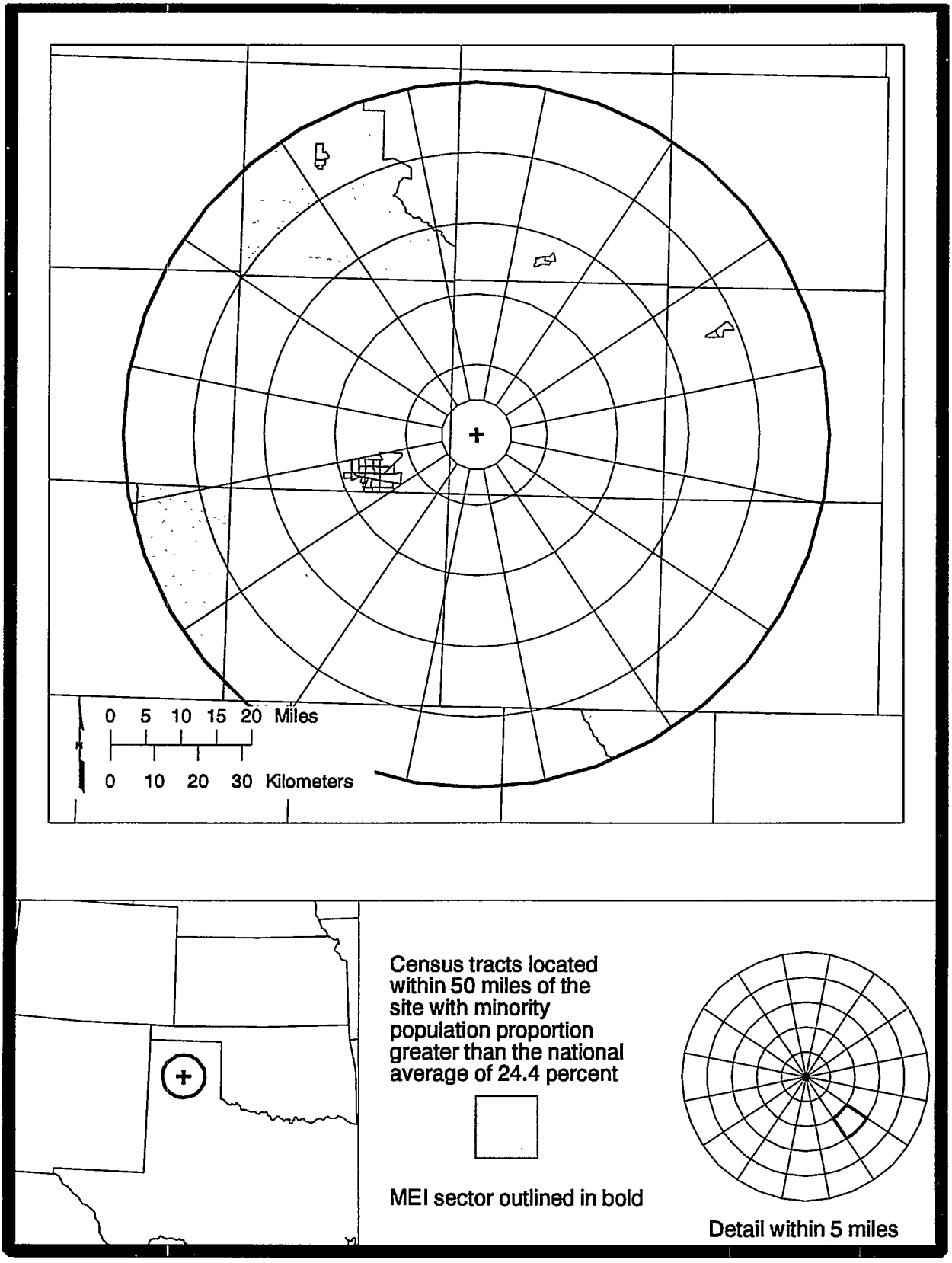


Figure C.4–17. Distribution of Minority Populations at the Pantex Plant.

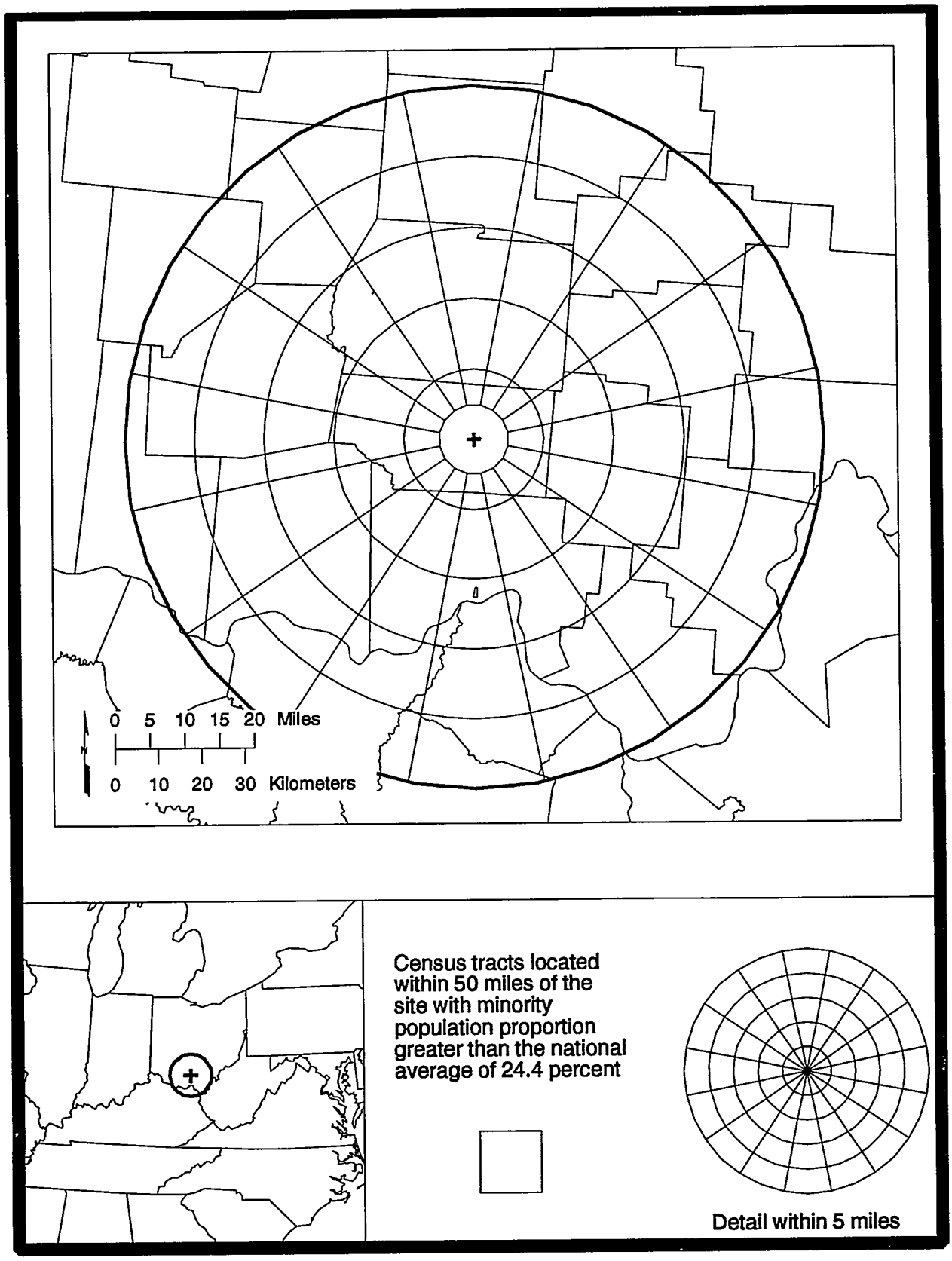


Figure C.4–18. Distribution of Minority Populations at the Portsmouth Gaseous Diffusion Plant.

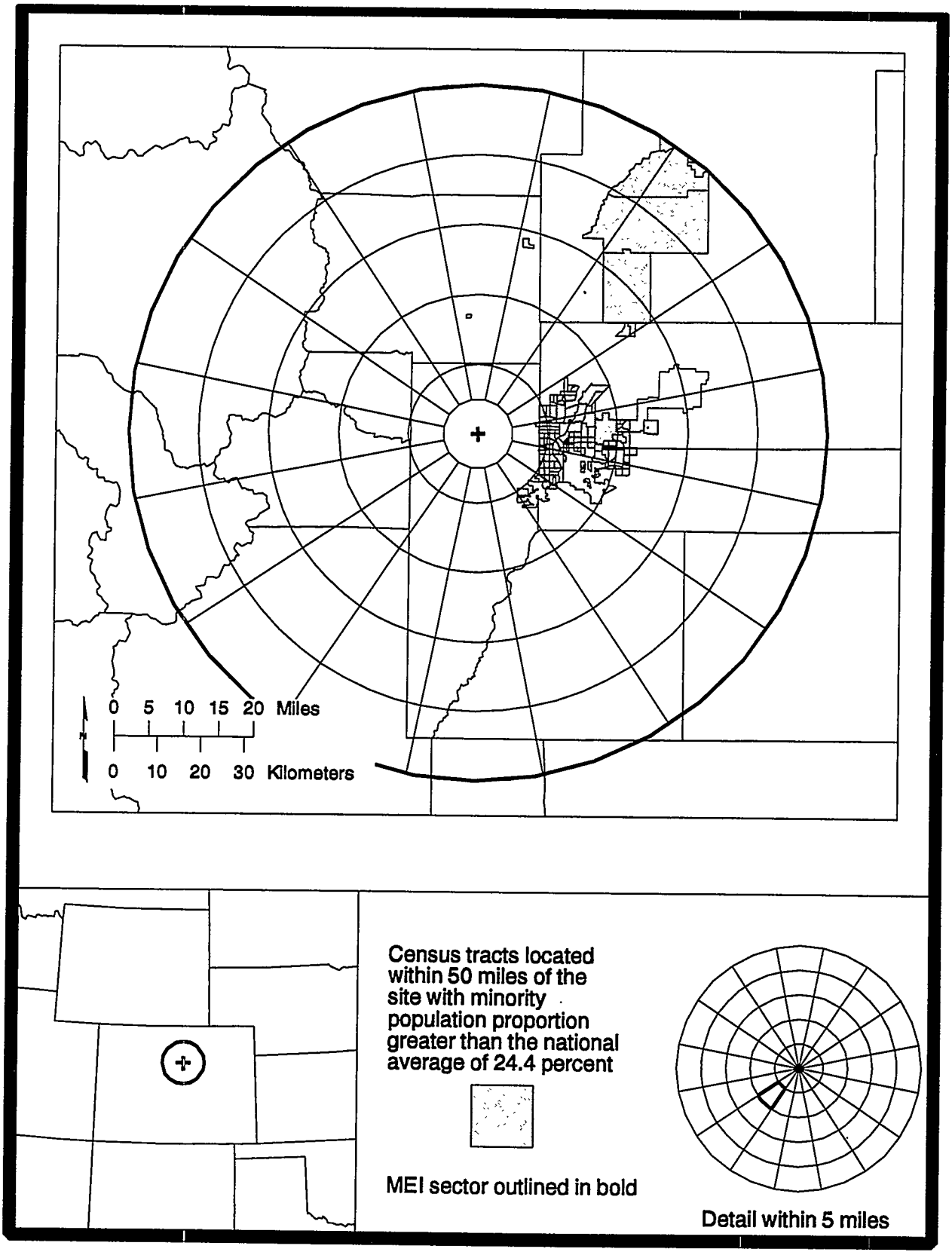


Figure C.4–19. Distribution of Minority Populations at Rocky Flats Environmental Technology Site.

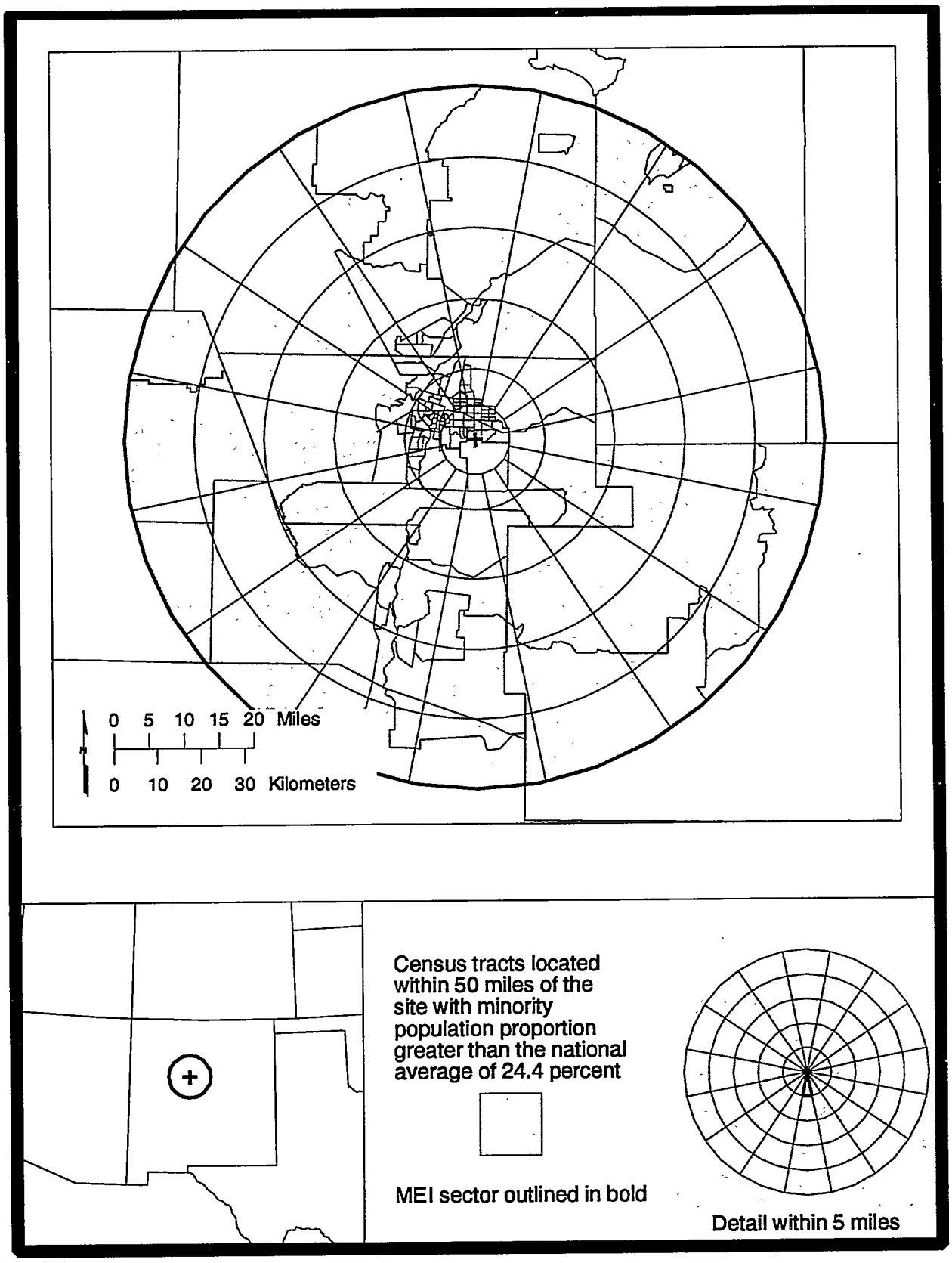


Figure C.4-20a. Distribution of Minority Populations at Sandia National Laboratories-New Mexico.

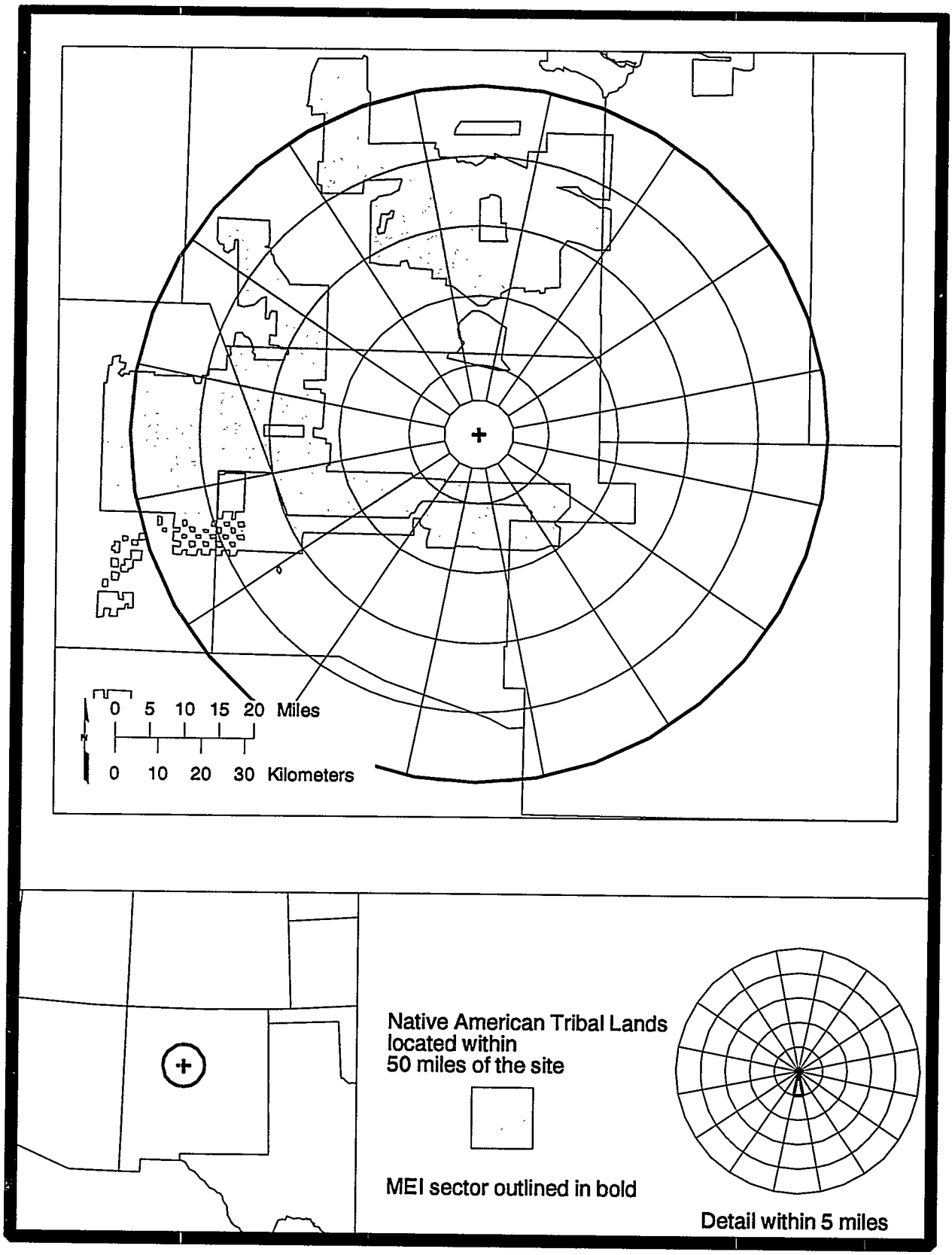


Figure C.4–20b. Locations of Tribal Lands at Sandia National Laboratories-New Mexico.

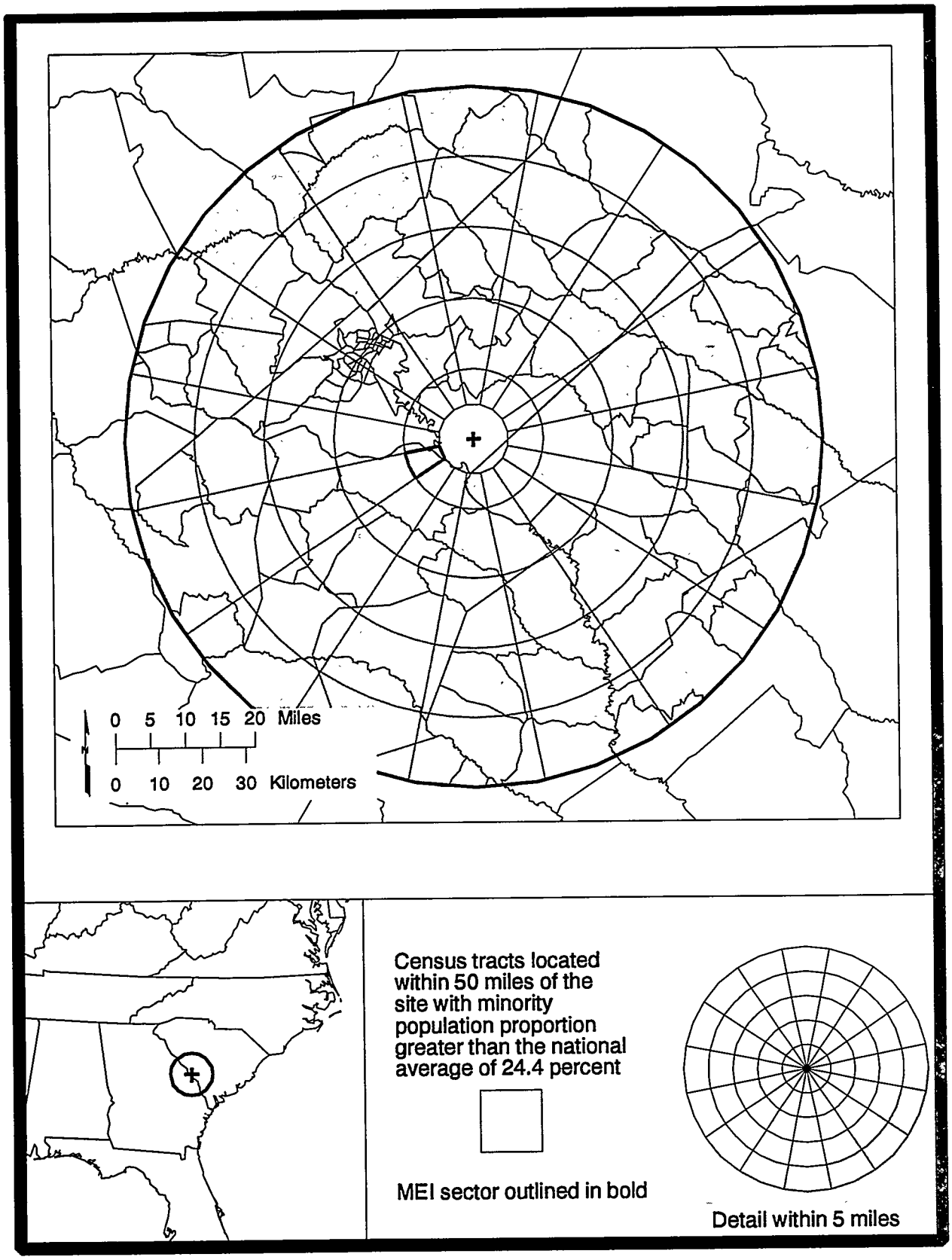


Figure C.4-21. Distribution of Minority Populations at the Savannah River Site.

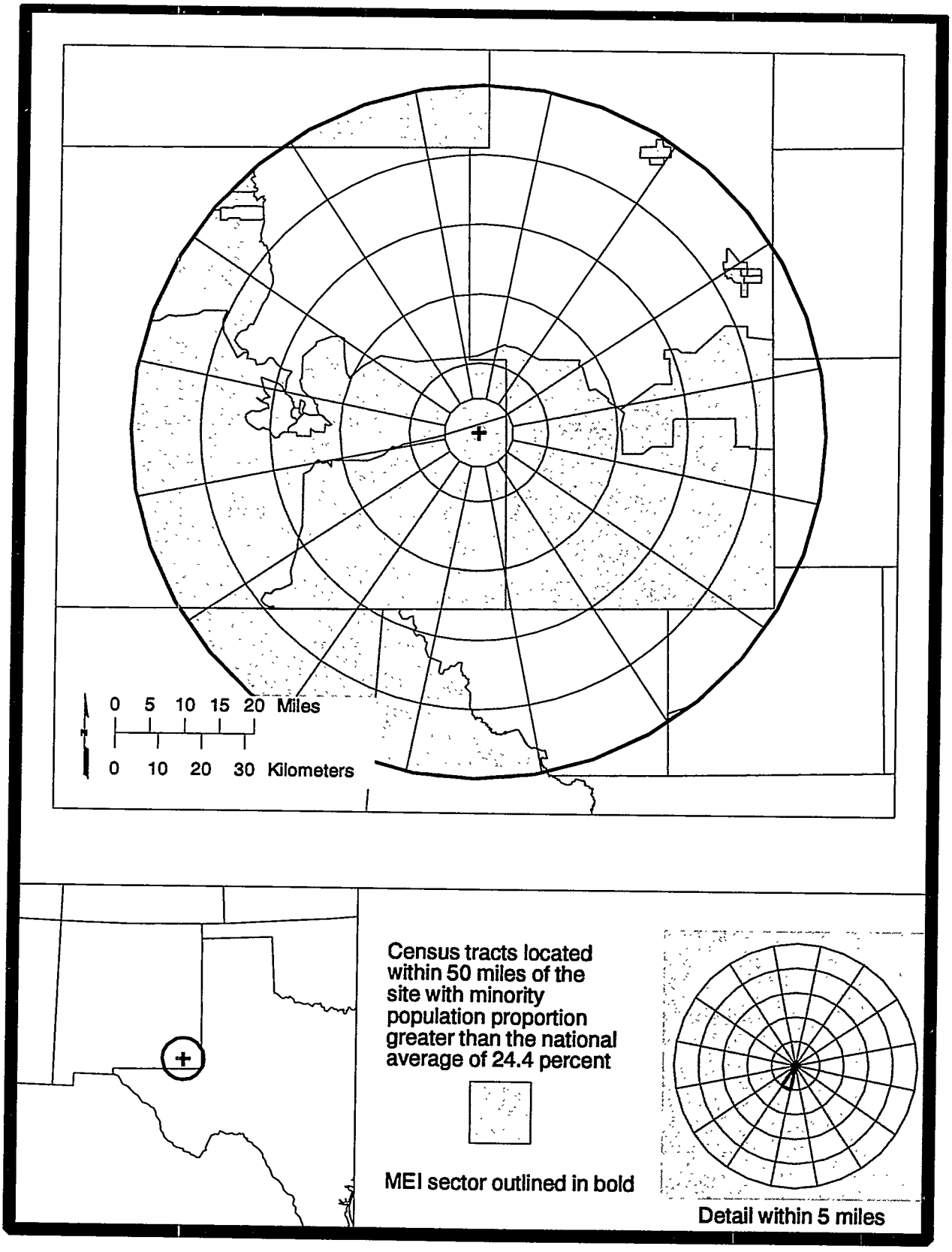


Figure C.4–22. Distribution of Minority Populations at the Waste Isolation Pilot Plant.

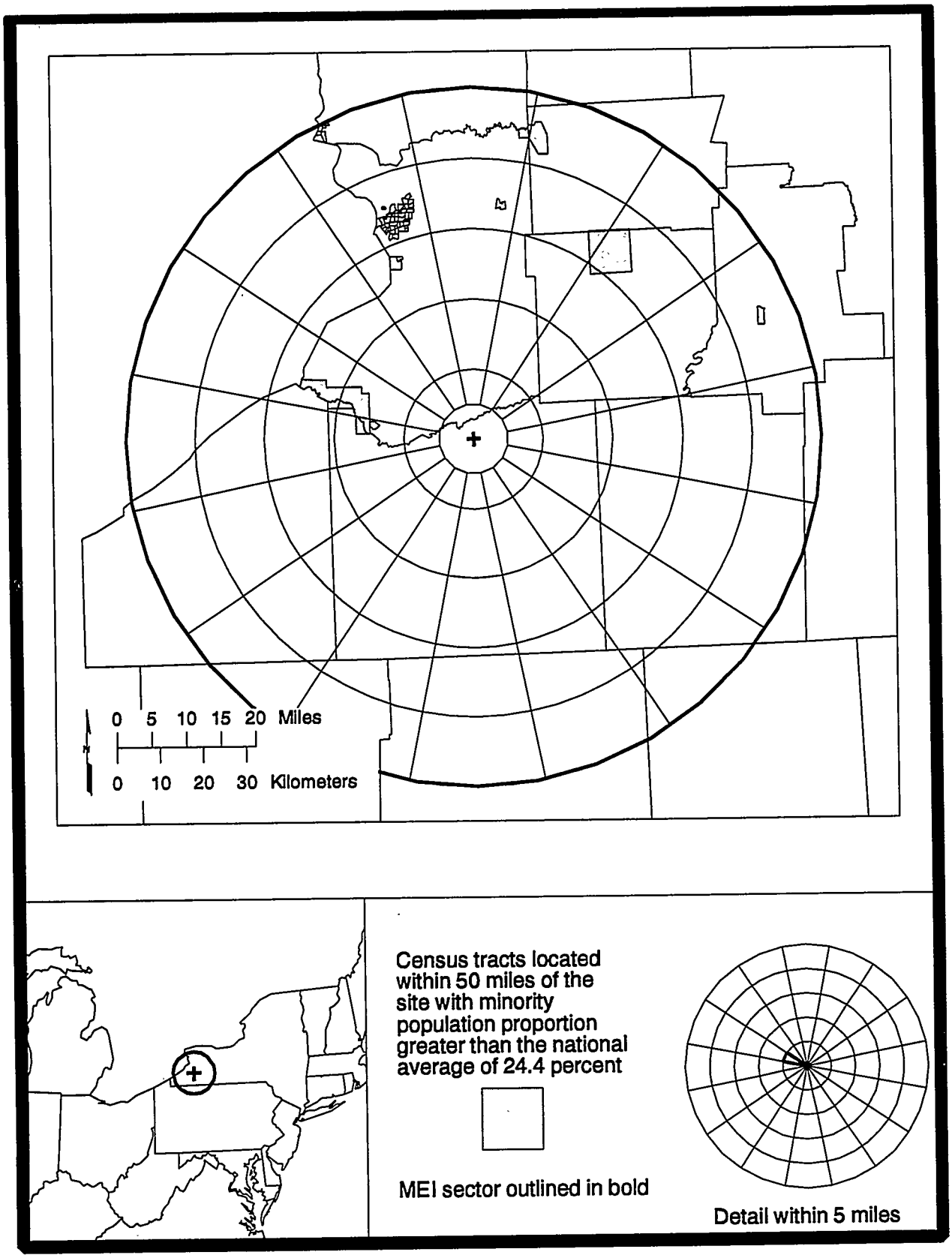


Figure C.4-23a. Distribution of Minority Populations at the West Valley Demonstration Plant.

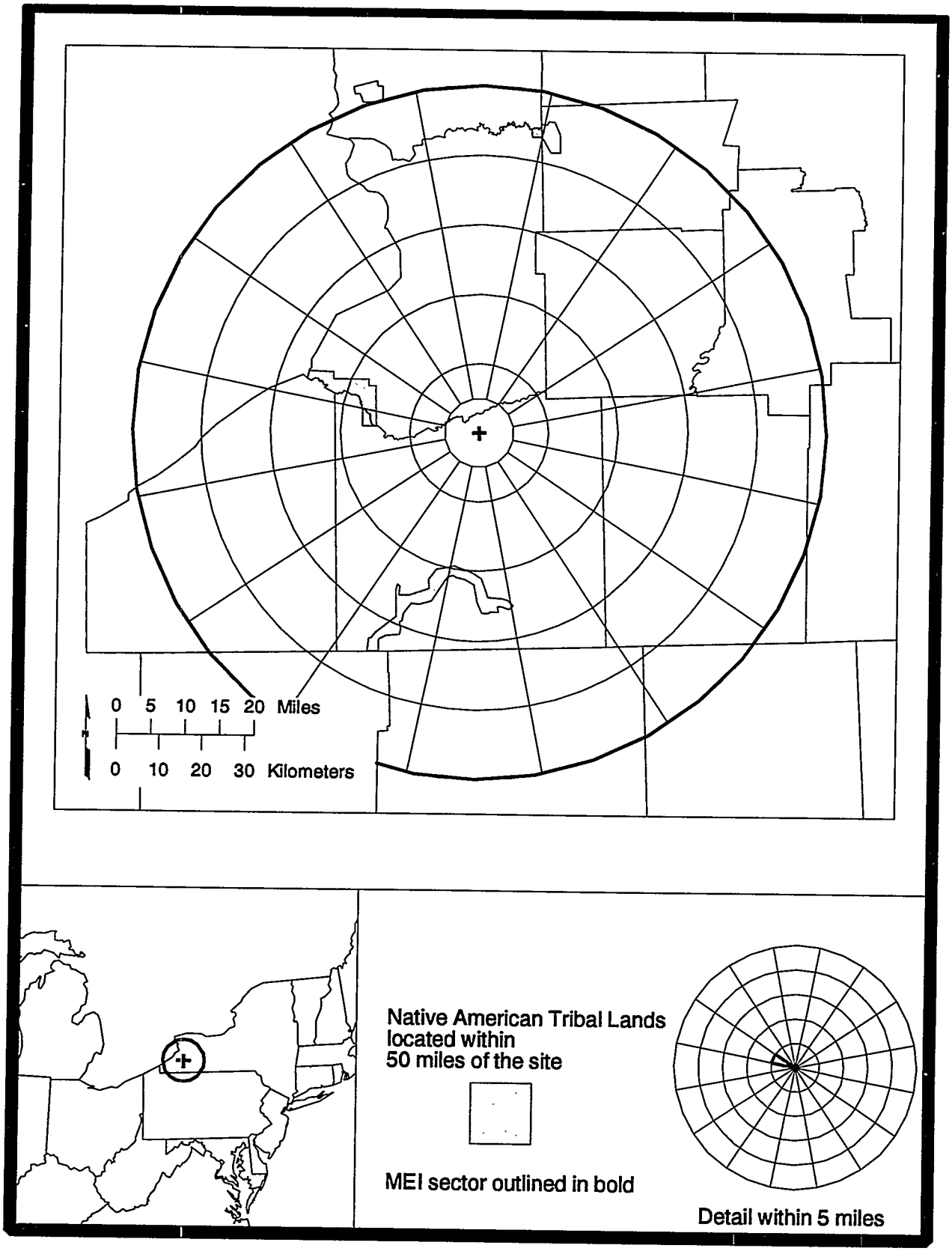


Figure C.4–23b. Locations of Tribal Lands at the West Valley Demonstration Project.

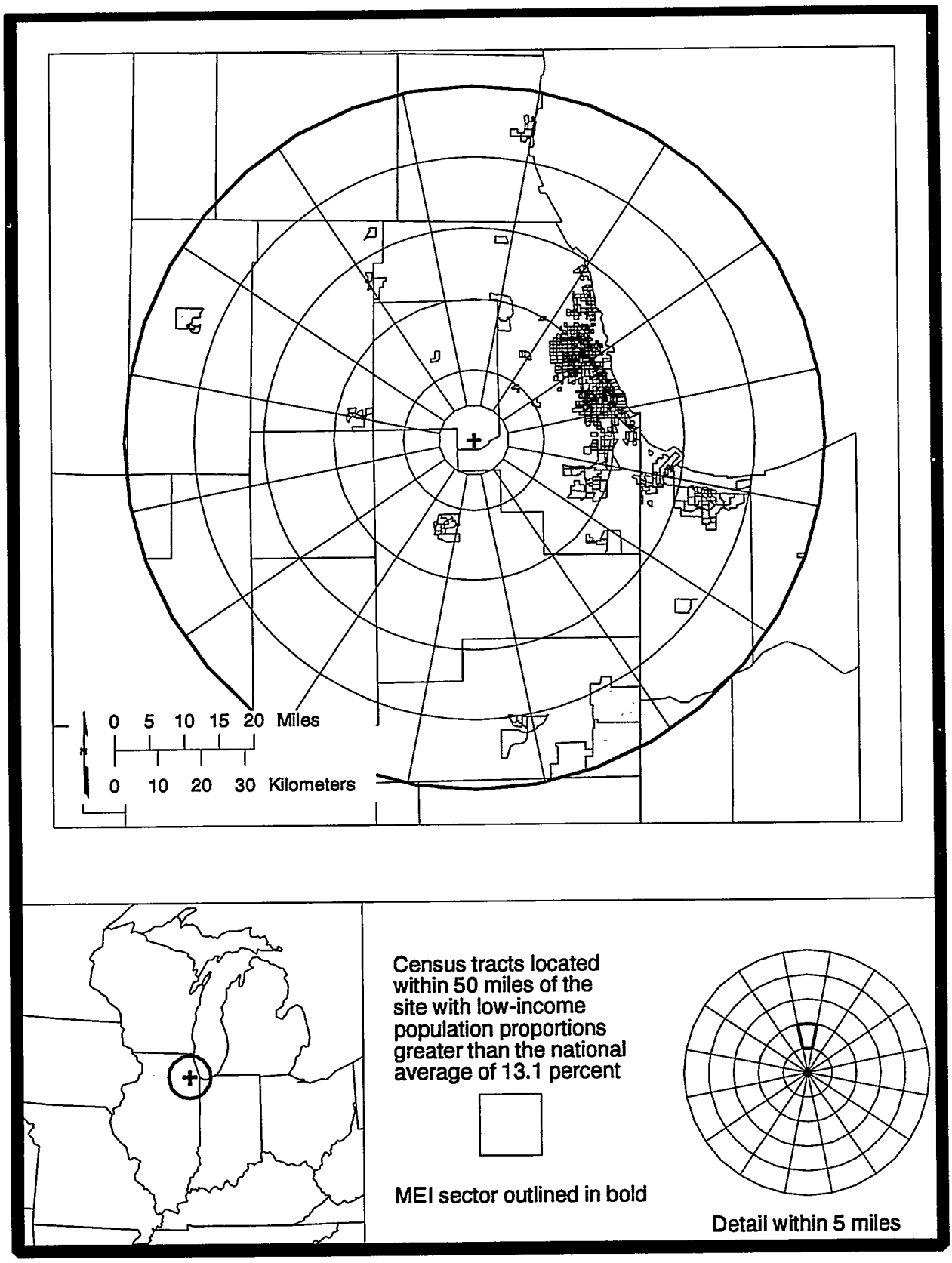


Figure C.4-24. Distribution of Low-Income Populations at Argonne National Laboratory-East.

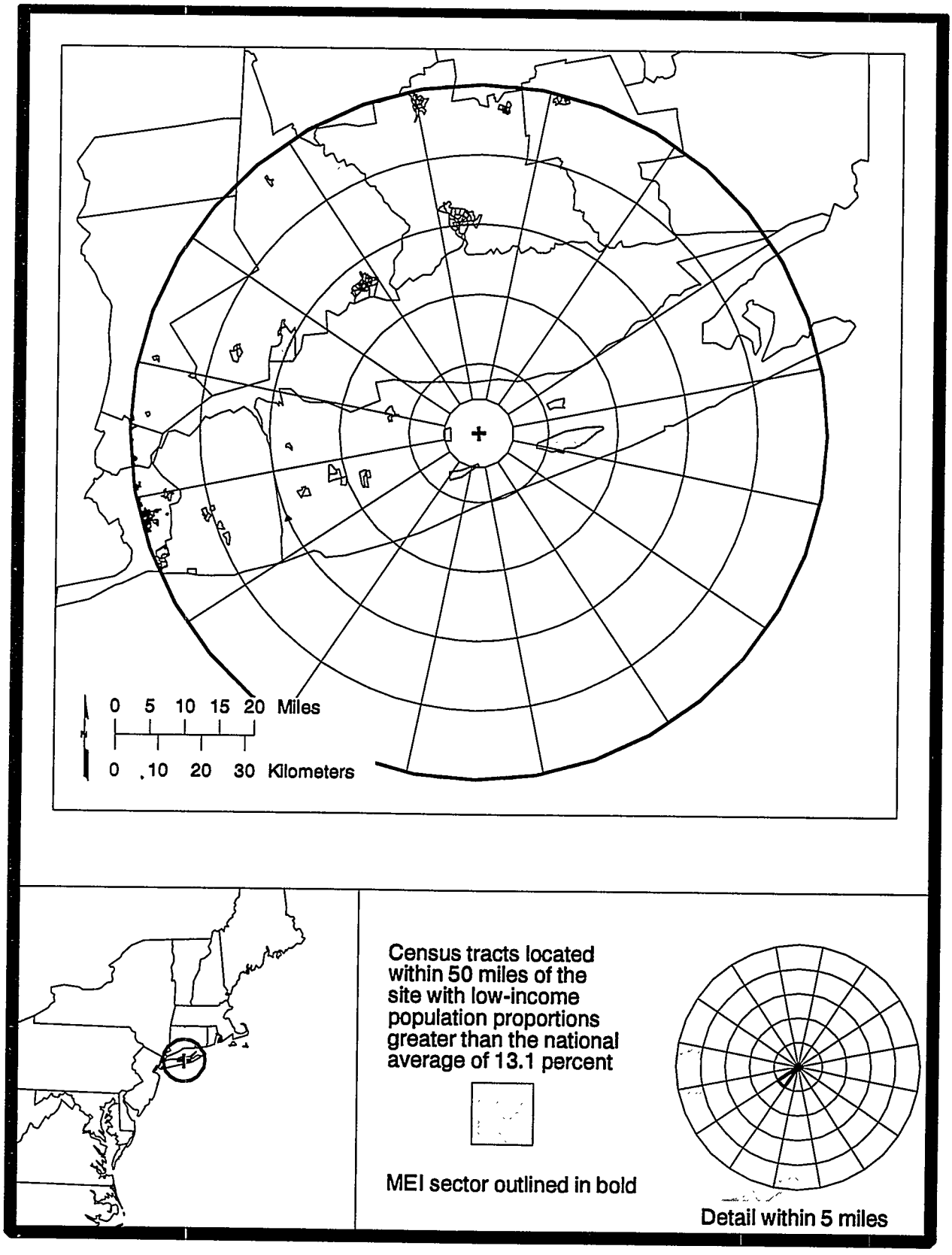


Figure C.4–25. Distribution of Low-Income Populations at Brookhaven National Laboratory.

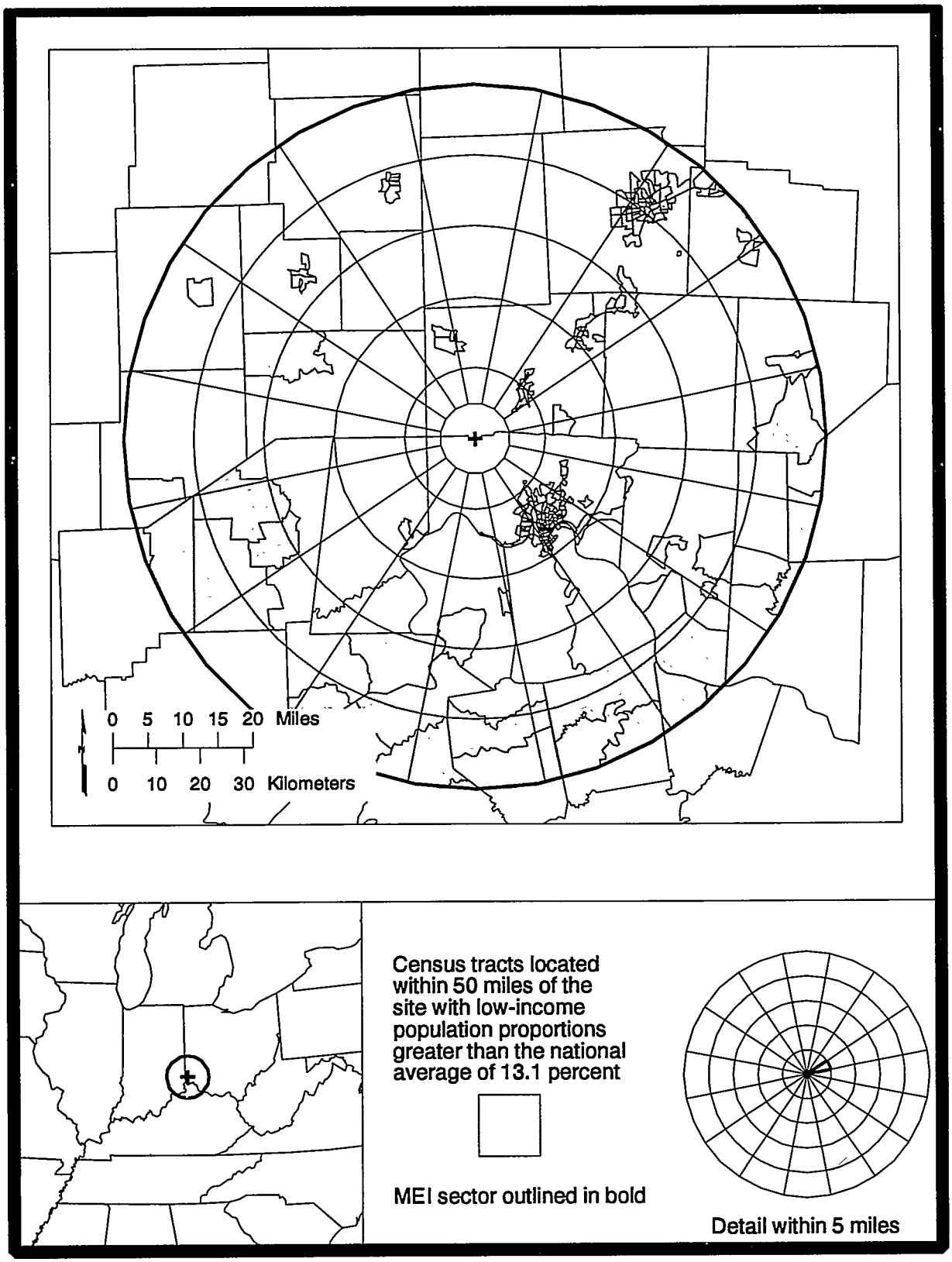


Figure C.4-26. Distribution of Low-Income Populations at Fernald Environmental Management Project.

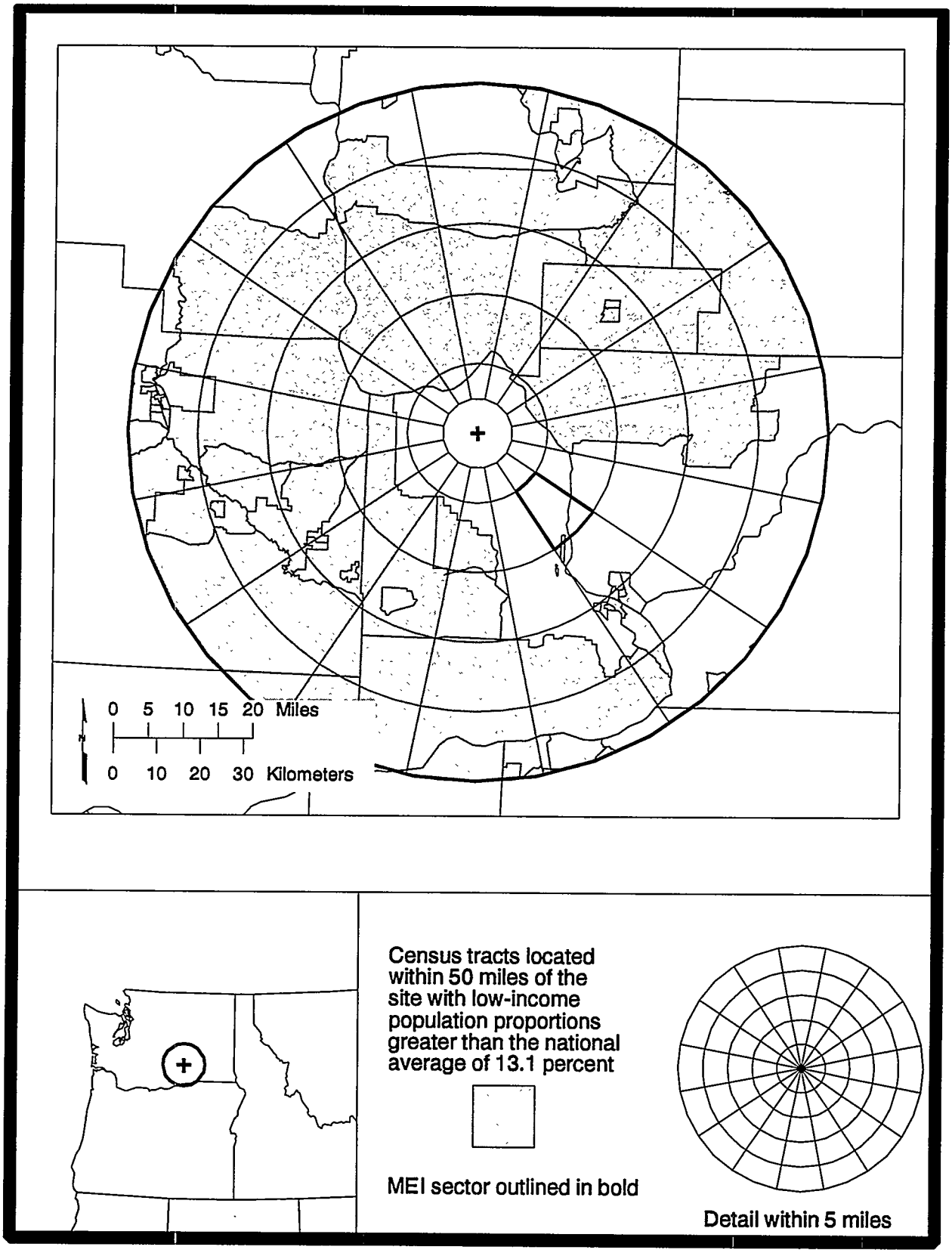


Figure C.4-27. Distribution of Low-Income Populations at the Hanford Site.

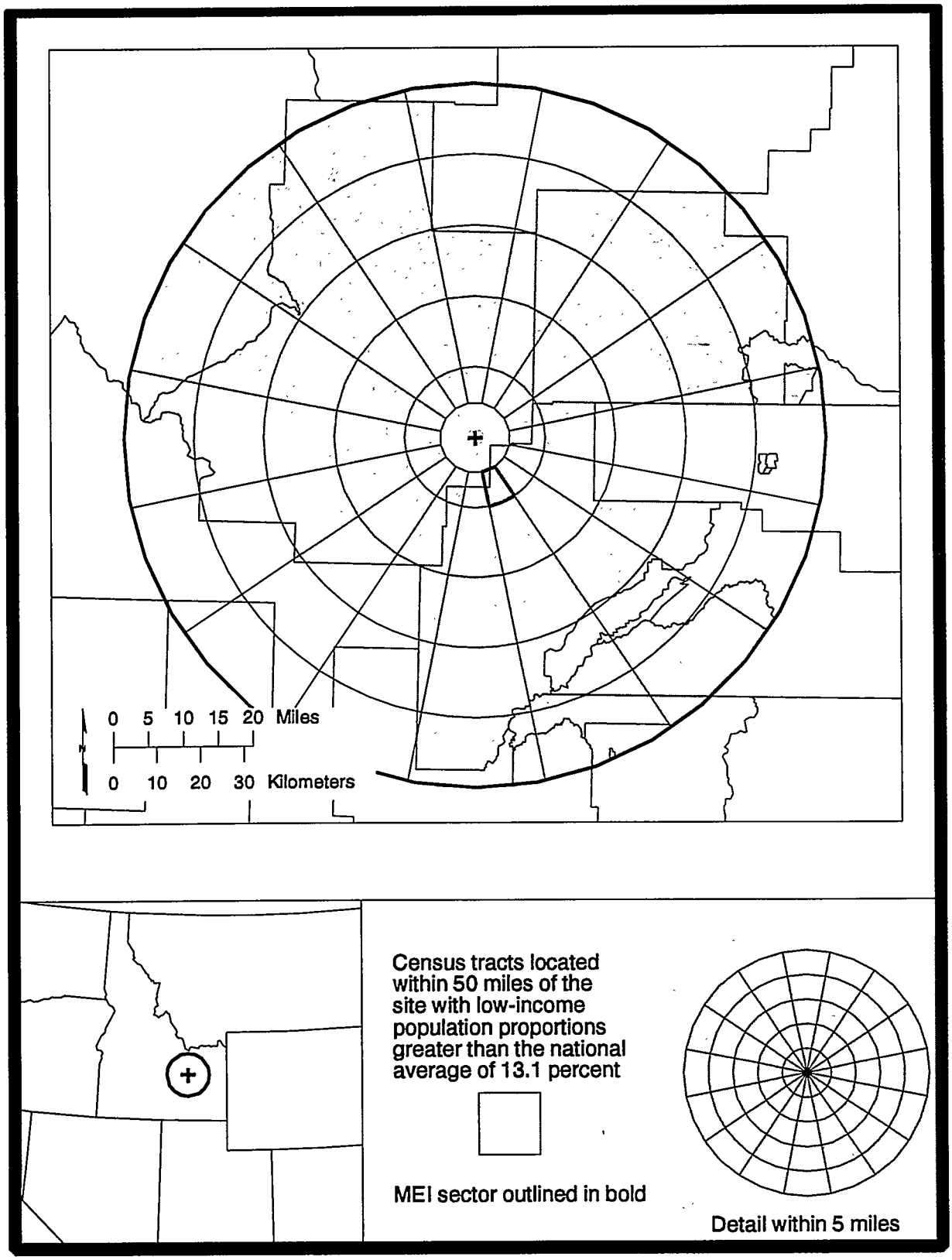


Figure C.4-28. Distribution of Low-Income Populations at Idaho National Engineering Laboratory.

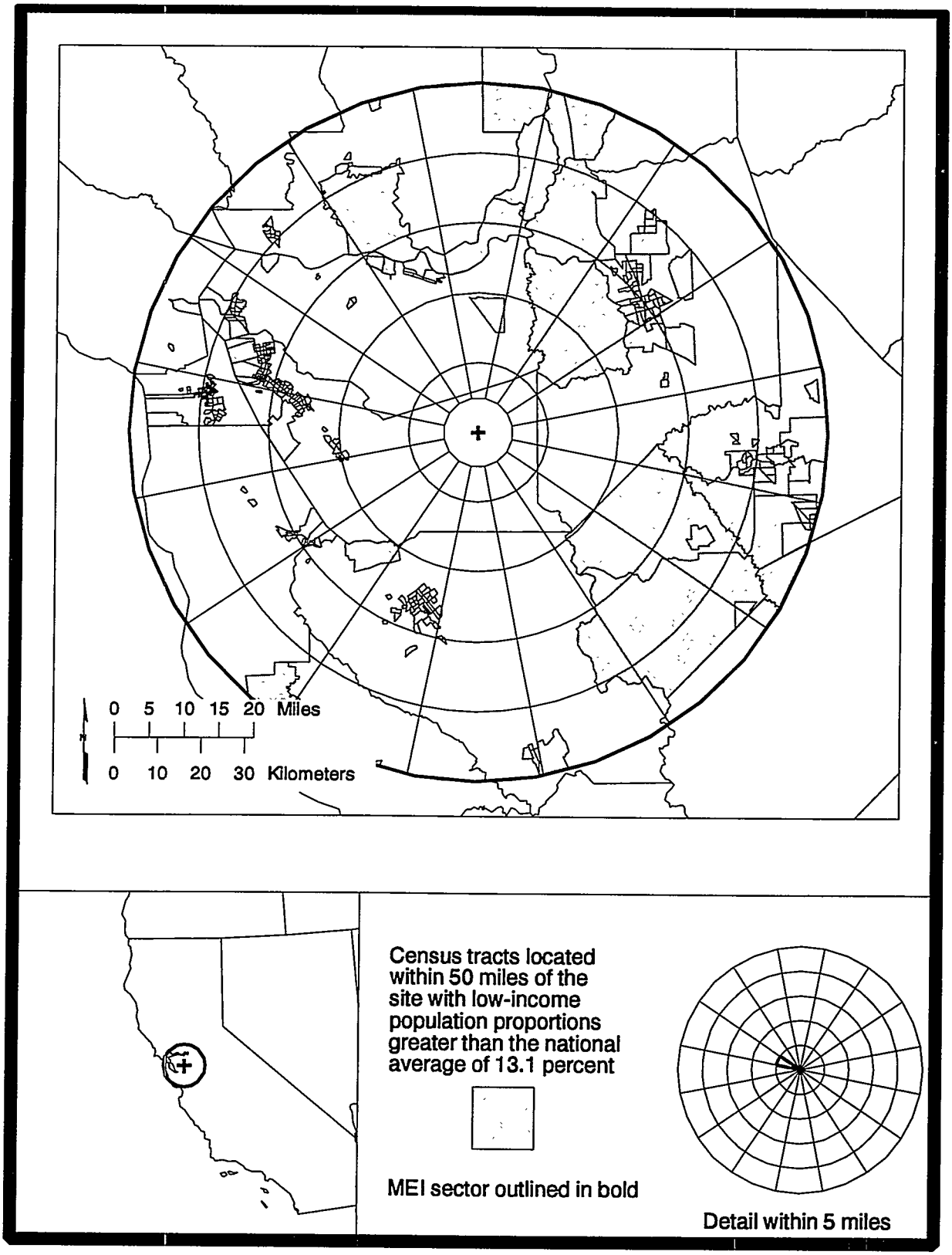


Figure C.4–29. Distribution of Low-Income Populations at Lawrence Livermore National Laboratory.

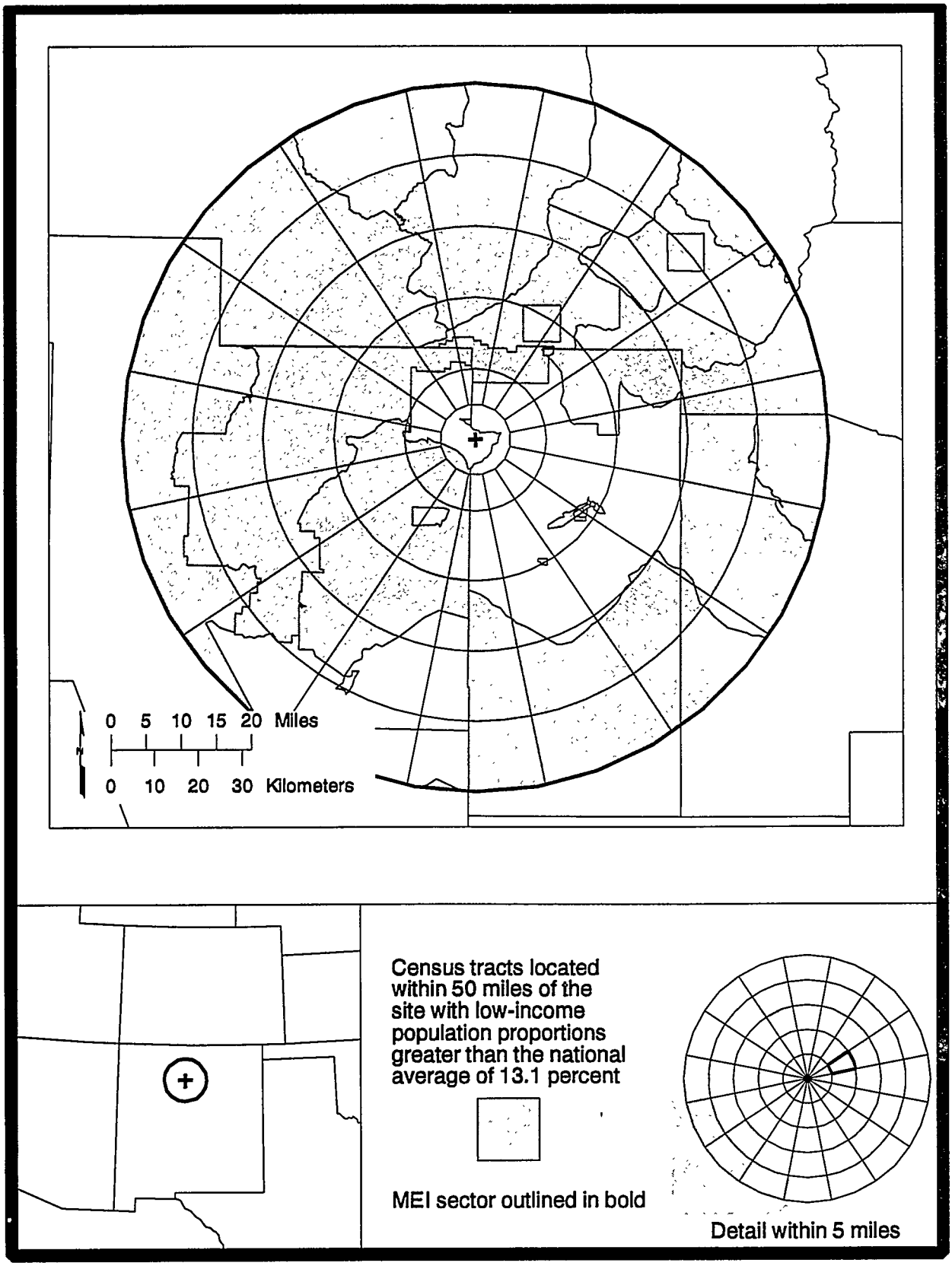


Figure C.4-30. Distribution of Low-Income Populations at Los Alamos National Laboratory.

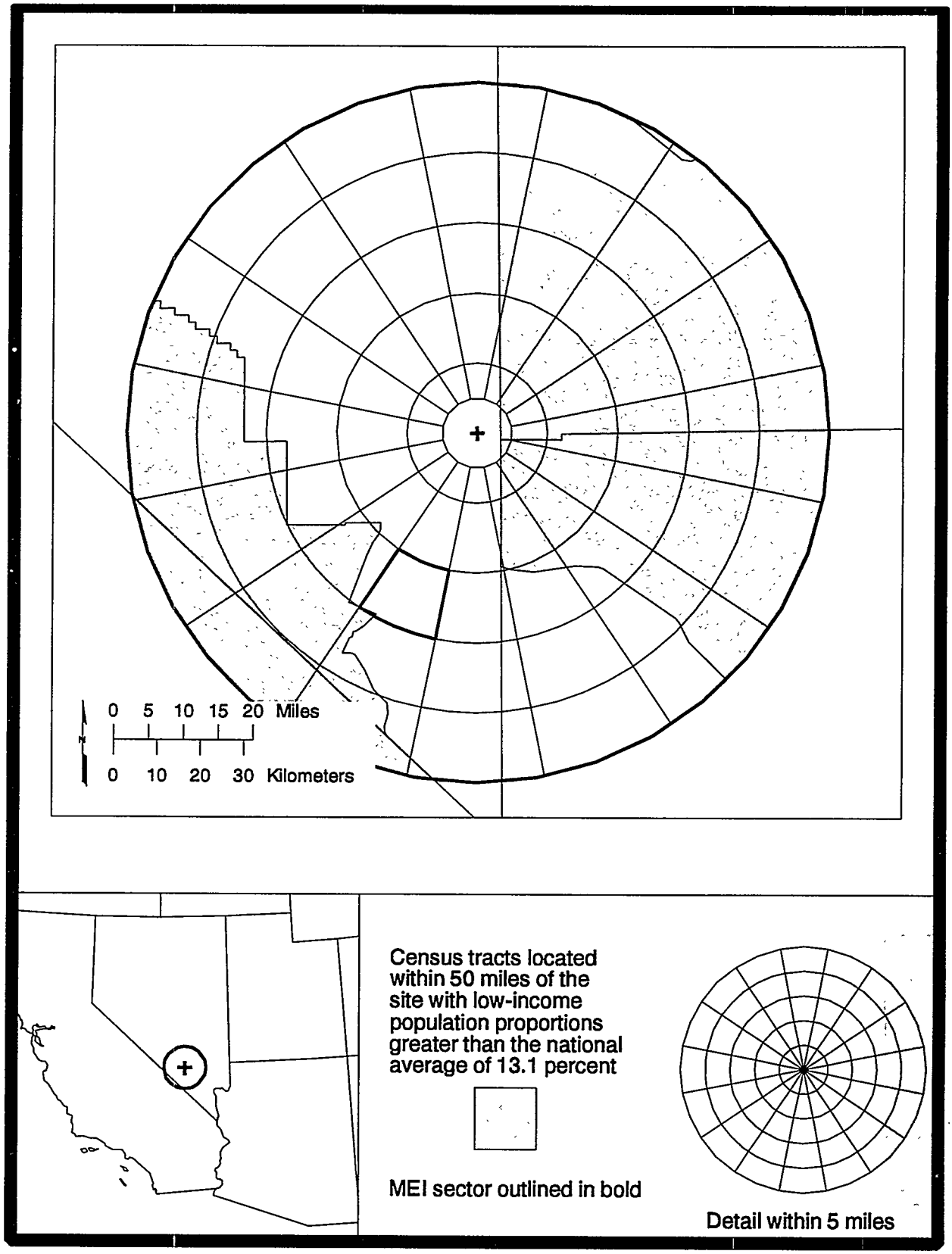


Figure C.4-31. Distribution of Low-Income Populations at the Nevada Test Site.

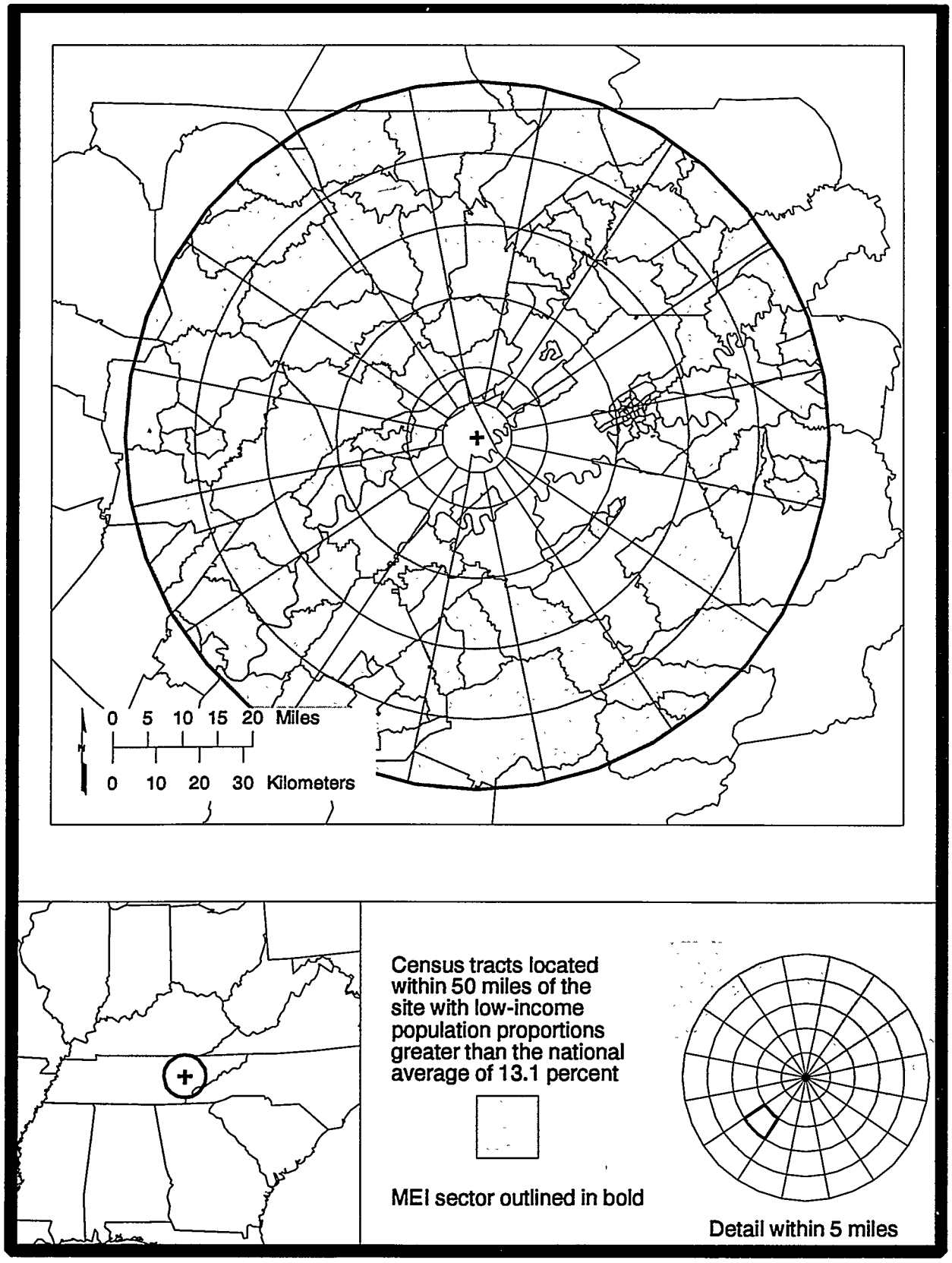


Figure C.4–32. Distribution of Low-Income Populations at the Oak Ridge Reservation.

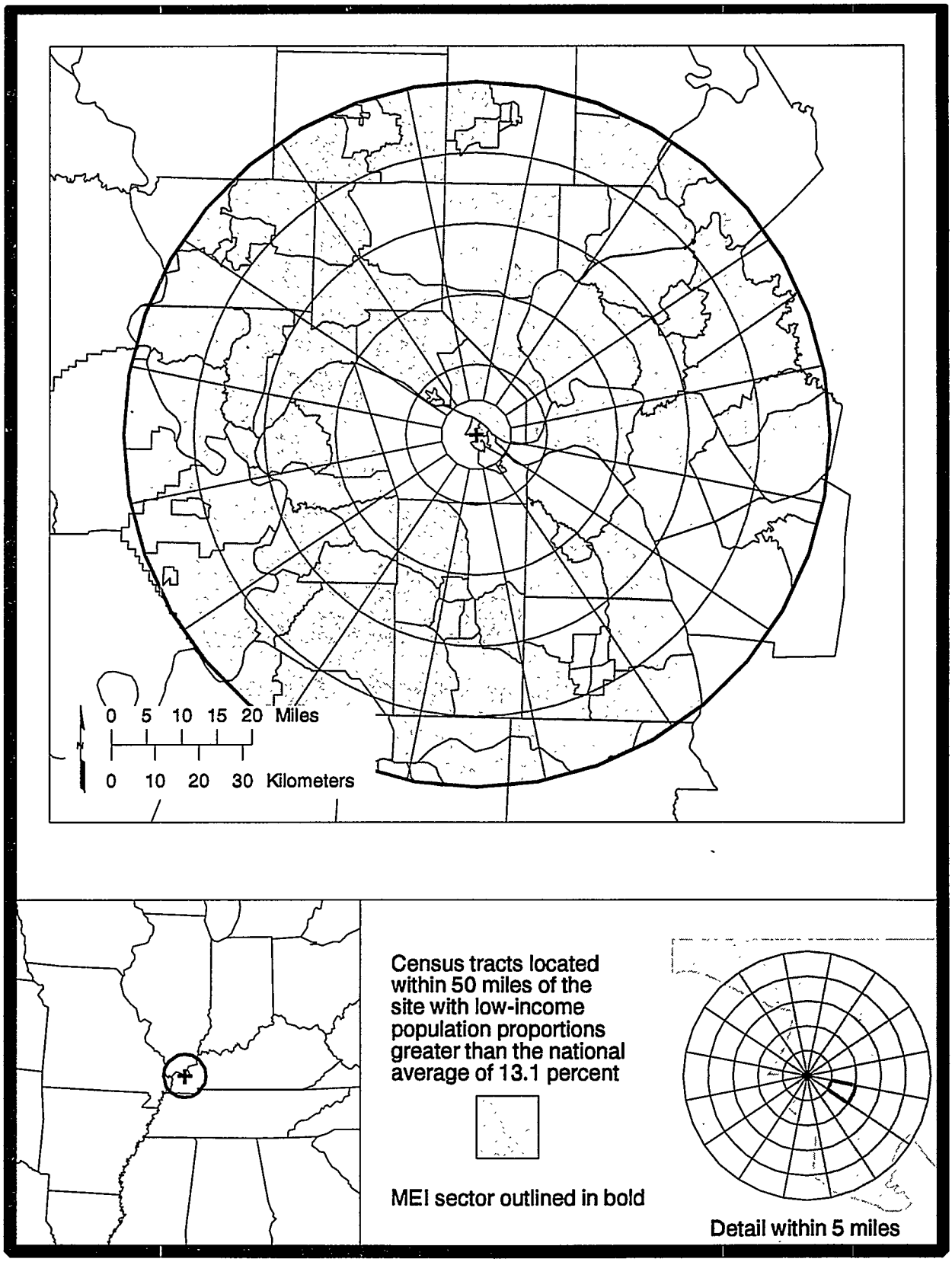


Figure C.4–33. Distribution of Low-Income Populations at the Paducah Gaseous Diffusion Plant.

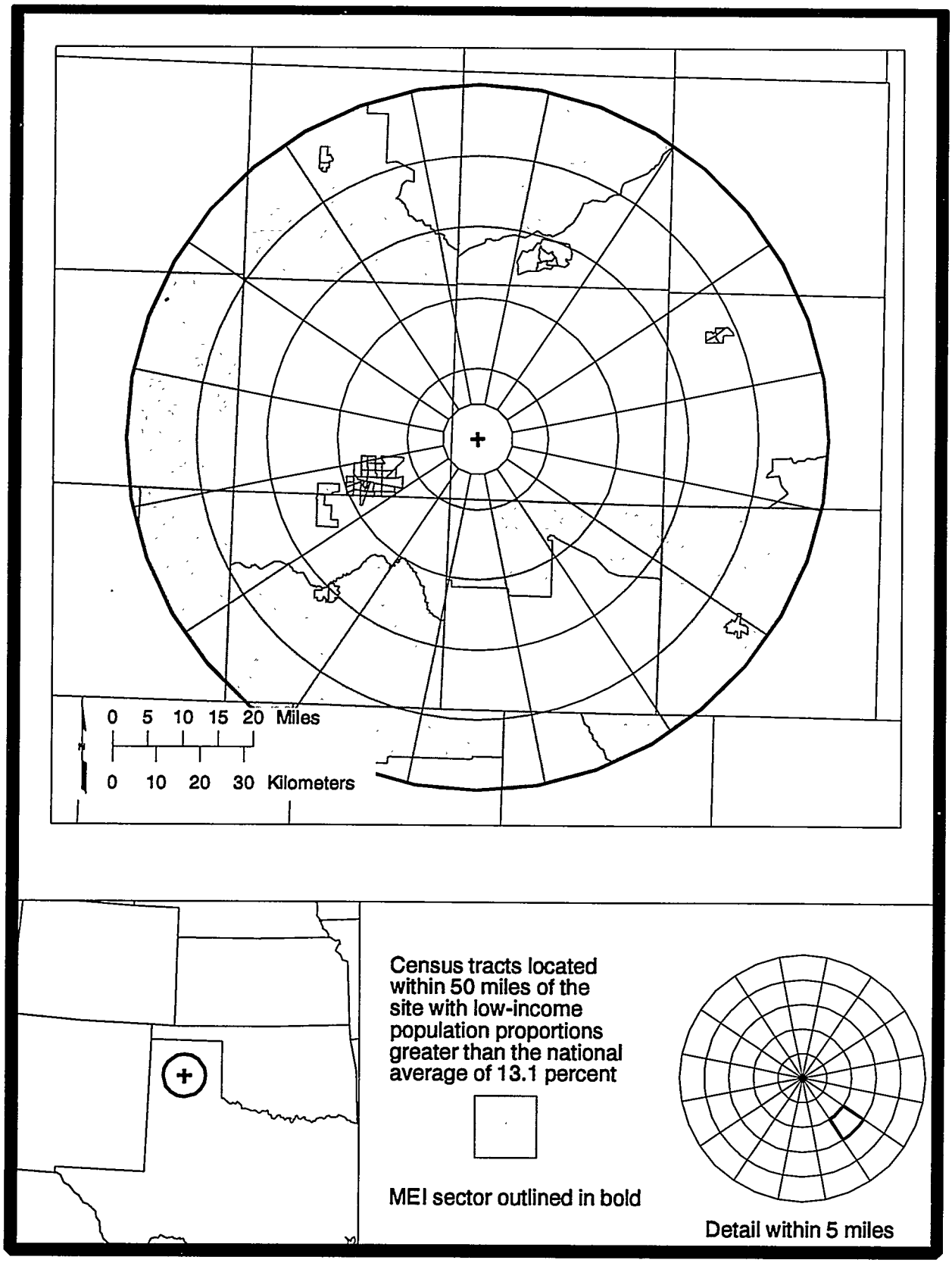


Figure C.4–34. Distribution of Low-Income Populations at the Pantex Plant.

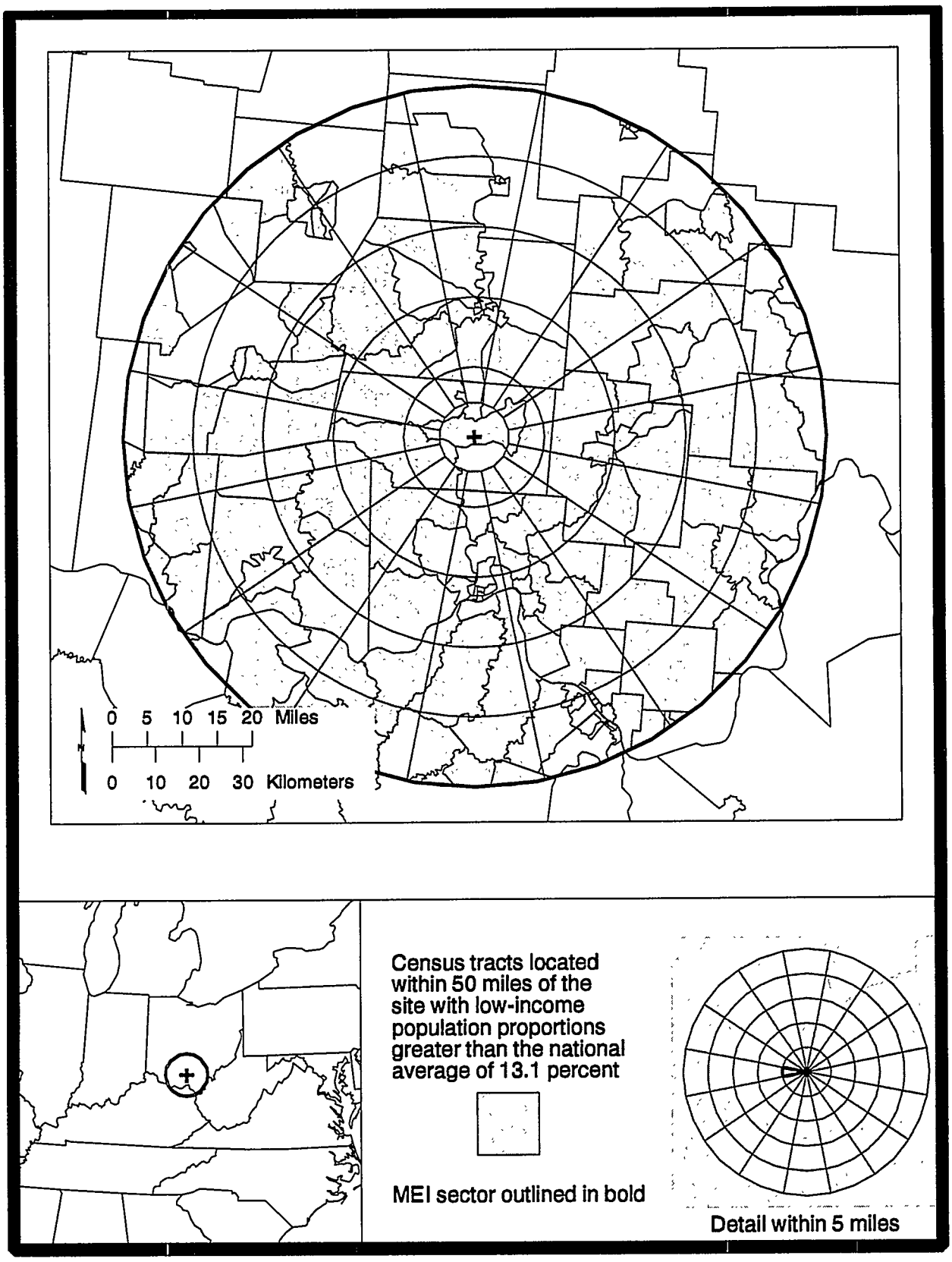


Figure C.4-35. Distribution of Low-Income Populations at the Portsmouth Gaseous Diffusion Plant.

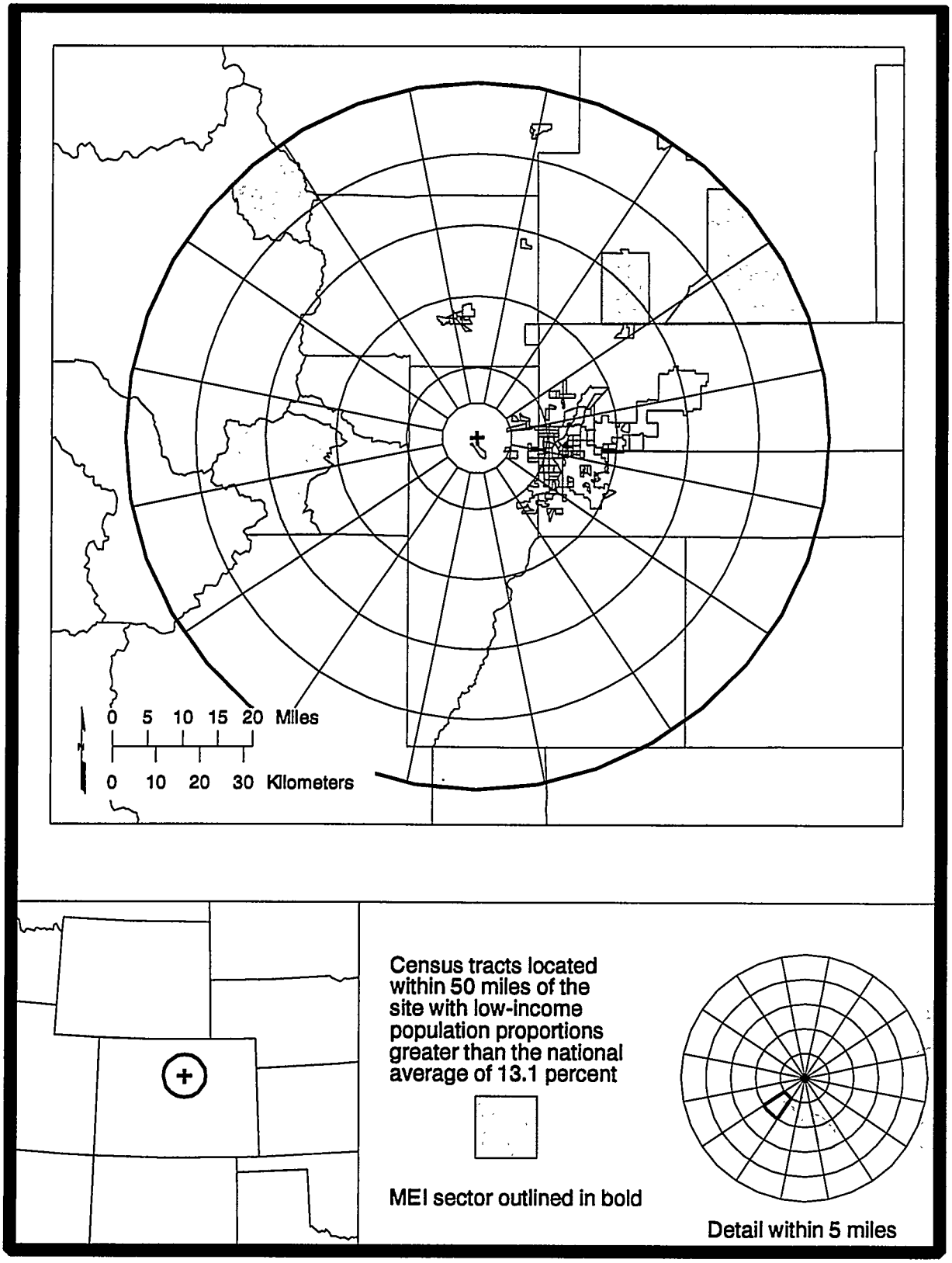


Figure C.4-36. Distribution of Low-Income Populations at Rocky Flats Environmental Technology Site.

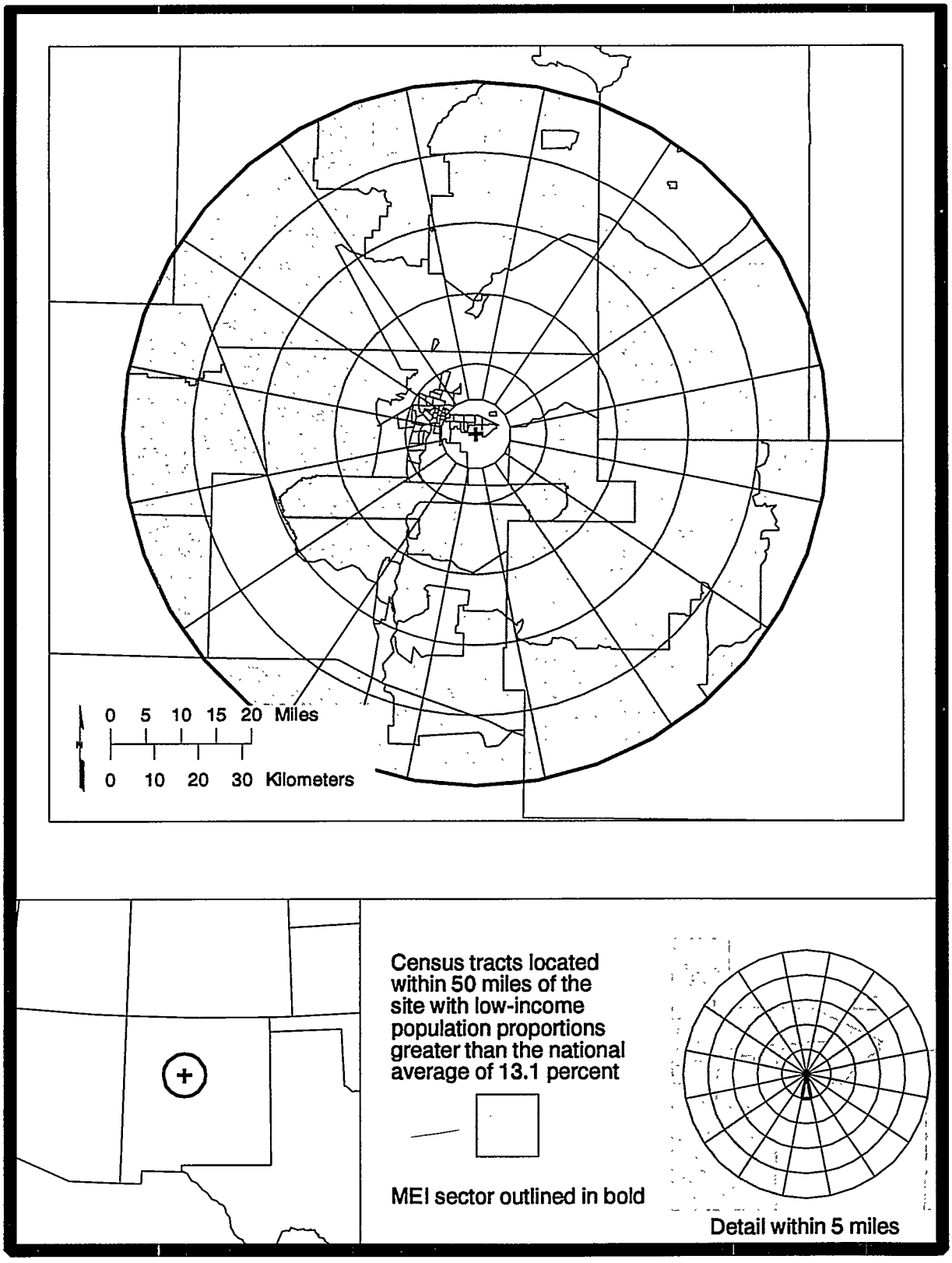


Figure C.4–37. Distribution of Low-Income Populations at Sandia National Laboratories-New Mexico.

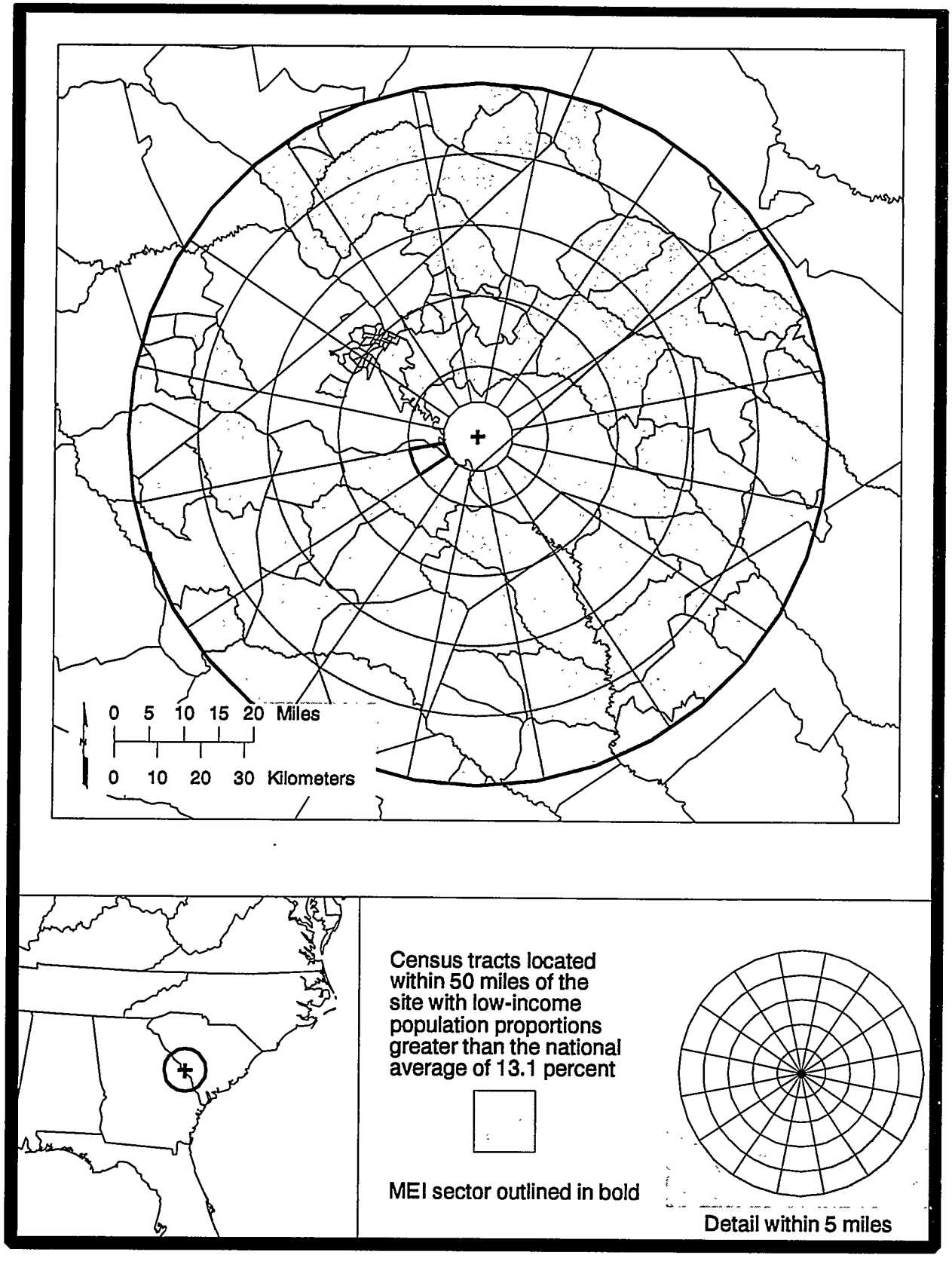


Figure C.4-38. Distribution of Low-Income Populations at the Savannah River Site.

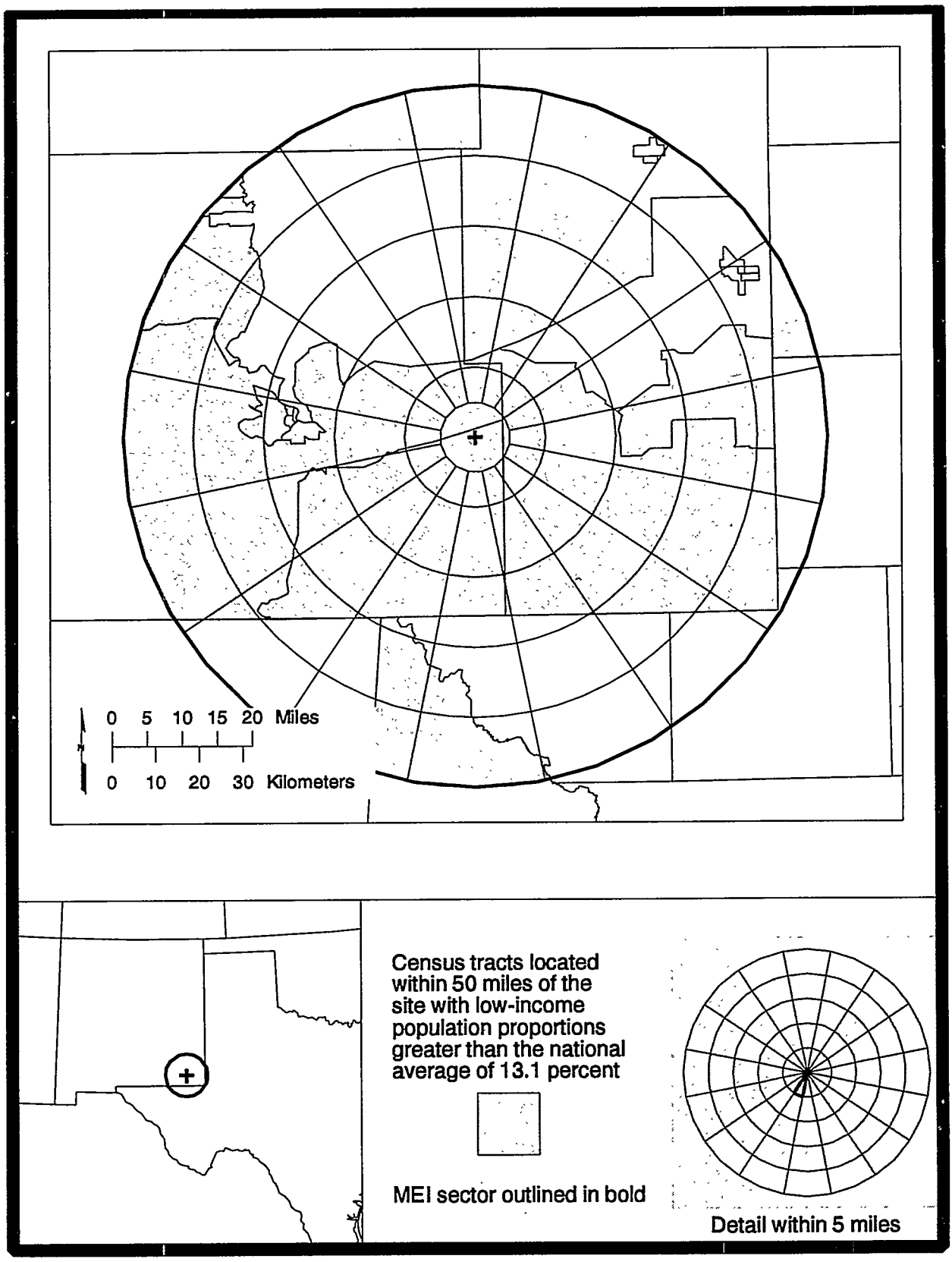


Figure C.4–39. Distribution of Low-Income Populations at the Waste Isolation Pilot Plant.

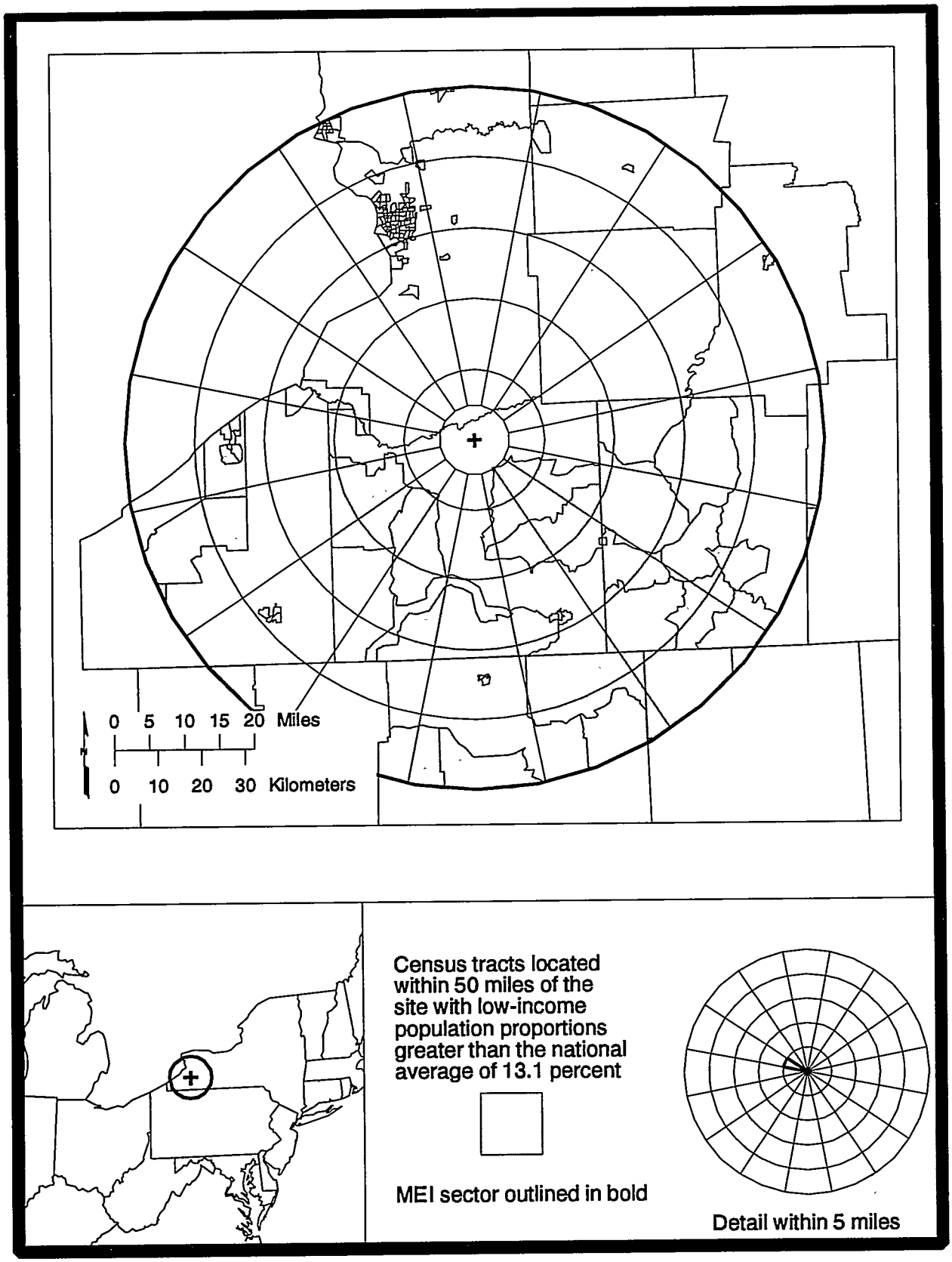


Figure C.4–40. Distribution of Low-Income Populations at the West Valley Demonstration Plant.

C.4.7.2.4 *Vulnerability of Minority and Low-Income Population due to Subsistence Food Consumption*

Section 4-4 of Executive Order 12898 directs Federal agencies, "whenever practical and appropriate, to collect and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence and that federal agencies communicate to the public the risks of these consumption patterns."

The potential environmental impacts of DOE activities on populations engaging in subsistence consumption could vary greatly depending on the precise location of a waste management facility at a particular site, the type of waste management facility, and the technology employed for the treatment or disposal of wastes at such a facility. In a prior NEPA review, DOE found the potential impacts associated with the consumption of fish and wildlife at INEL, Hanford, SRS, NTS, and ORR to be small or no different from the potential impacts on the general population (DOE, 1995c). DOE could not determine whether the impacts from fish consumption at WVDP were disproportionately high and adverse (DOE, 1996c). However, DOE predicted a high long-term risk of contracting cancer for a variety of groups (including Native Americans) for the No Action and long-term management alternatives for the Tank Waste Remediation System (TWRS) at Hanford (DOE, 1996d). The subsistence consumption scenario used for TWRS "has not received a complete review by the scientific community nor has it been approved by the potentially affected tribes" (DOE, 1996d).

To assemble and disseminate information on subsistence hunting and fishing, DOE began publishing *A Department of Energy Environmental Justice Newsletter: Subsistence and Environmental Health*, in the spring of 1996. The three goals of the newsletter are (1) "to provide useful information about the health implications of consuming contaminated fish, wildlife, livestock products or vegetation," (2) "to provide information about projects and programs at DOE and other federal and state agencies that address the problems associated with consuming contaminated fish, wildlife, livestock products, or vegetation," and (3) "to receive relevant information from readers." In addition to the newsletter, DOE has a new project underway

Internet Access is Available for DOE's Environmental Justice Information

Subsistence and Environmental Health Newsletter On-line:
http://www.em.doe.gov/health/

Environmental Justice Strategy for the Department of Energy:
http://www.em.doe.gov/stake/envjus.html

Table C.4-25. Factors Contributing to the Possibility of Subsistence Consumption of Fish and Wildlife

Site	Federally Recognized Native American Groups[a]	Distance to Major Surface Water Bodies	Population in the 50-Mile Region of Influence (in millions)	Percentage Minority (within a 50-mile radius)	Percentage of Low Income Populations
Sites with Higher Possibility of Subsistence Consumption					
Hanford	Yes	On site	0.35	25.8	18.8
INEL	Yes	NA[b]	0.11	10.2	12.5
LANL	Yes	At site boundary	0.27	48.1	13
RFETS	Yes	On site	1.98	19.7	9.8
SNL	Yes	6 miles	0.61	45.1	14.8
SRS	Yes	At site boundary	0.59	37.8	18
WIPP	Yes	NA	0.10	36.9	21.6
WVDP	Yes	On site	1.54	11.6	12.2
Sites with Intermediate Possibility of Subsistence Consumption					
NTS	Yes	NA	0.01	12.8	12.6
ORR	None	At site boundary	0.88	6.1	16.2
PGDP	None	<2 miles	0.50	9.1	19.1
PORTS	None	<1 mile	0.61	3.2	20.8
Sites with Lower Possibility of Subsistence Consumption					
ANL-E	None	<1 mile	8.03	33.5	11.4
BNL	None	On site	5.26	21.4	5.4
FEMP	None	<1 mile	2.64	13.2	11.8
LLNL	None	NA	6.31	40.9	9.5
Pantex	None	NA	0.27	19.8	15.2

[a] The presence of a federally recognized Native American group was assumed to be the most important indicator of potential subsistence fishing and hunting. The remaining factors are listed in descending importance from left to right.
[b] NA = not applicable; no major surface water bodies within the region of influence.

to identify what information is being collected on subsistence consumption by other Federal agencies and to serve as a clearinghouse for such information.

In a recent article reviewing the literature on subsistence consumption, ANL found that (1) "the majority of the studies that have been conducted to date are focused on site- or region-specific exposure concerns. . . . At present, it is unclear whether the findings of these studies are representative of consumption and exposure levels among minority populations at a national level;" (2) "a large number of risk assessment studies focusing on fish and wildlife consumption examined whole populations without distinguishing between consumption and exposure patterns of specific ethnic (or other) subpopulations;" (3) "the vast majority of studies have focused on fish consumption as an exposure pathway. Few examined wildlife consumption and contamination, and even in such cases the studies were not motivated by minority exposure concerns;" and (4) "the majority of the studies identified found rates of fish and shellfish consumption among minority populations to be significantly higher than for the population as a whole" (Elliot, 1994).

With regard to the impacts analyzed in this PEIS, and in the absence of subsistence consumption data by population subgroups, DOE prepared Table C.4–25 using the following criteria and assumptions weighted in order of importance, to identify groups of sites that may be near minority and low income populations potentially engaging in subsistence consumption.

- Proximity of Tribal Lands to DOE sites (the presence of Native Americans near DOE sites is assumed to create a greater possibility for subsistence consumption)
- Distance of the DOE site to major surface water bodies (populations nearer water are assumed to have a greater possibility of subsistence consumption of fish)
- Population density in the 50-mile region of influence around the site (rural residents are assumed to have a greater possibility of engaging in subsistence hunting and fishing)
- Proximity and concentration of minority and low-income populations to DOE sites (higher concentrations of minority and low-income populations are assumed to have a greater potential for subsistence consumption)

The 17 major DOE sites appear in the table in three groups: those with the higher possibility for subsistence consumption, those with intermediate possibilities for subsistence consumption, and those with the lower possibilities for subsistence consumption. As Table C.4–25 shows, more rural sites with recognized Native American groups are assumed more likely to engage in subsistence hunting and fishing. These sites include

Hanford, INEL, LANL, RFETS, SNL, SRS, WIPP, and WVDP. Sites of intermediate concern include NTS, ORR, PGDP, and PORTS, because of the respective sites' rural surroundings, the presence of Native American populations, the presence of minority or low-income populations, or the presence of surface water on site. While sites like ANL-E and LLNL have a large percentage of minorities, both sites are in urban areas with populations of 8 and 6.3 million respectively. Because of these factors, ANL-E and LLNL are listed along with BNL, FEMP, and Pantex as having a lower possibility of populations who principally rely on fish and/or wildlife for subsistence.

C.4.8 Land Use Impacts

The land use impacts analysis evaluated the potential for the management alternatives for the five waste types to adversely affect land use at the sites by comparing the amount of land required for proposed waste treatment, storage, or disposal facilities with the amount of land designated for future waste management operations in the site development plans for the 17 major sites. For those of the 17 sites not having a portion of the site designated for waste operations, the land required for waste management activities was compared with an estimated amount of land suitable for development. This estimate was made by subtracting from the total installation acreage the known or estimated acreage of land in existing structures, sensitive habitats including wetlands, topographic and surface water features, and other features such as wildlife management areas and cultural resources. At sites where the land requirement constitutes 1% or more of designated or suitable land, a potential for impacts is noted in the waste type impacts discussion and the percent required is listed in a summary table for the site/alternative. The text then discusses the severity of impacts depending on how great a portion of the available land is required and includes an indication of the likelihood of conflicts with land uses adjacent to the site. Where the land requirements for waste management activities exceeds the amount of land designated or suitable, the analysis indicates that significant land use impacts are likely. Apart from the analysis of the percent of suitable site land used, the analysis also indicates whether the description of future uses at the sites given in the site development plans appears to indicate a potential conflict between those planned uses and the uses proposed under the waste type alternatives.

C.4.9 Infrastructure Impacts Methodology

Construction and operation of waste management facilities at the sites will increase the sites' use of water supply, wastewater treatment facilities, and electrical power systems and will increase traffic on site roads.

The impacts of the waste management alternatives on site water, wastewater, and power systems were evaluated using estimates of the percentage of existing system capacity the new requirements represented. Where the new requirements were substantial, they were added to current use rates and the sum compared to the existing supply capacities of those systems. Site transportation infrastructure impacts were assessed indirectly using increased site employment as an indicator of increased stress on the system. Impacts to community infrastructure systems were assessed using estimated waste management project-induced population increases as an indicator of increased demand on those systems. The impacts assessment evaluated the separate effects of the construction and operations phases for each alternative for each waste type.

C.4.9.1 Site Infrastructure Impacts

The site infrastructure impacts analysis focused on the effects of the WM alternatives on the 17 major sites' water supply, wastewater treatment, and electrical power infrastructure systems. Data on new infrastructure requirements under each alternative are described in Section C.3.2 of this appendix. Current use rate and existing capacity data are described in PEIS Chapter 4 on the Affected Environment and in the Affected Environment Technical Report.

New project requirements of less than 5% of existing capacity were considered likely to have negligible or minor impacts on an infrastructure system and were not further evaluated. Moderate or major impacts were considered possible where increases in system requirements were 5% or greater. These cases were further evaluated on a site by site basis. Major impacts were considered possible where new requirements caused system capacity to be approached or exceeded. Therefore, any increase of 5% or greater that caused the total site use rate to exceed 90% of available capacity, was considered to have the potential to cause a major infrastructure impact. In such cases, site infrastructure may require substantial expansion or construction of new systems to meet the added demand. Such projects would have associated costs and environmental impacts beyond the direct impacts of the waste management facilities.

Where site infrastructure capacity information was not available, the new requirements were evaluated as a percentage of current use. In these cases, new requirements of less than 5% of current use were considered likely to have negligible or minor impacts. Increases in requirements from 5% to less than 15%

were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential to cause major impacts.

Site transportation infrastructure impacts were evaluated indirectly by comparing new site employment to existing site employment as an indicator of increased stress on site transportation systems. New site employment of less than 5% of current employment was considered likely to have negligible or minor impacts. Site employment increases from 5% to less than 15% were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential to cause major impacts.

C.4.9.2 Community Infrastructure Impacts

Community infrastructure would be affected indirectly by any substantial increase in population caused by the influx of labor to implement the WM alternatives. Community infrastructure impacts were evaluated by comparing estimated population increases with current population levels as an indicator of increased use rates of community infrastructure systems. This analysis was based on the in-migration estimates and 1990 regional population data described in the social impacts analysis (see Section C.4.6). Population increases of less than 5% of current (1990 census) population levels were considered to have the potential to cause negligible or minor impacts. Increases of 5% or greater were considered to have the potential to cause moderate impacts, and increases of 15% or greater were considered to have the potential for major infrastructure impacts.

C.4.9.3 Site and Community Infrastructure Baseline

Baseline water, wastewater, and power information can be found in the Affected Environment chapter and appendix. The information is summarized below. Proposed resource requirements under the alternatives are compared to the current capacity to determine whether increased use will impact the infrastructure systems. Site employment information is provided in the socioeconomic impacts discussion and is summarized in Table C.4–26. Proposed increases in site employment under the various alternatives is compared to current site employment to determine possible impacts to transportation infrastructure.

Table C.4-26. Baseline Infrastructure Data for the 17 Major DOE Sites

Site	Water (gpd)		Wastewater (gpd)		Power (MW)		Site Employment
	Current Use	Capacity	Current Use	Capacity	Current Use	Capacity	
ANL-E	625,000	1,800,000	434,000	2,600,000	23	NA	4,455
BNL	3,500,000	6,000,000	1,000,000	2,300,000	35	47	3,557
FEMP	400,000	1,600,000	2,180,000	2,270,000	33	NA	1,939
Hanford	9,510,000	79,060,000	158,000	200,000	550	NA	14,394
INEL	5,242,000	30,630,000	254,000	unlimited	42	NA	11,813
LANL	4,100,000	10,000,000	NA	1,000,000	68	120	6,199
LLNL	717,000	2,520,000	400,000	1,680,000	61	100	8,173
NTS	1,360,000	2,780,000	140,000	338,000	30	45	7,086
ORR	18,300,000	40,200,000	2,000,000	4,100,000	116	660	21,544
PGDP	15,000,000	30,000,000	400,000	1,750,000	1,564	3,040	1,740
Pantex	500,000	1,500,000	275,000	545,000	13	1,523	2,891
PORTS	14,000,000	37,000,000	350,000	1,200,000	1,537	1,929	2,386
RFETS	272,000	1,000,000	150,000	500,000	18	35	7,365
SNL	1,000,000	4,030,000	548,000	NA	35	50	8,596
SRS	1,600,000	5,000,000	500,000	750,000	80	175	17,319
WIPP	14,000	540,000	12,000	185,000	NA	NA	932
WVDP	70,000	110,000	70,000	70,000	3	7	1,100

Notes: gpd = gallons per day; NA = not available. Data for baseline infrastructure represent onsite use only. Wastewater use and capacity are based on sanitary waste. No process wastes are included.

C.4.10 Cultural Resources Impacts

The potential for cultural resources to be affected by waste management activities was considered by using the estimated acreage of site disturbance to construct waste management facilities under each waste-type alternative as an estimate of the area of potential cultural resource effects and as a comparative indicator of the extent of the cultural resource survey requirements at each site. Cultural resources impacts were not directly evaluated in the PEIS because the analysis would require identification of specific locations of proposed waste management facilities.

C.4.10.1 Cultural Resources Considered

The cultural resources considered in this analysis include prehistoric and historic resources, and Native American resources. Paleontological resources, though not cultural in origin, are also included because of their recognized value and similar need for protection.

C.4.10.1.1 *Prehistoric and Historic Properties*

A "historic property" is an archeological site, standing structure, or traditional cultural property that is listed or is potentially eligible for listing on the National Register of Historic Places (36 CFR 60). Requirements for the assessment of historic properties for the PEIS are met through compliance with Section 106 of the National Historic Preservation Act of 1966 (16 USC 470), as amended, with implementing regulations contained in 36 CFR 800. In general, Federal agencies are required to determine the effects of proposed actions on significant historic properties within a defined area of potential effects.

C.4.10.1.2 *Native American Resources*

Resources that may be of concern to Native Americans may be structures, regional locations, natural features, native plants, objects and other materials that are considered to be of value to contemporary Native American groups for traditional, religious, or ceremonial purposes. Examples of these resources can include burial grounds, sacred sites, and areas, materials for the production of sacred objects and traditional implements, and botanical, biological, and geological resources of ritual importance. Impacts to these areas include both direct physical impacts (destruction, loss of access) and indirect social and economic effects. Several laws and Executive Orders are specifically applicable to the protection of Native American resources including American Indian Religious Freedom Act of 1978 (42 USC 1996), the Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001 *et seq.*), and Executive Order 13007 regarding sacred sites. Determination of potential impact to these sites is similar to that for other historic properties.

C.4.10.1.3 *Paleontological Resources*

Paleontological materials and features are the physical remains of life forms (fossils) from a former geologic age. These include the remains of animals, plants, or trace fossils such as impressions, burrows or tracks. Although paleontological resources are not treated with the same level of specificity as archeological or historic properties, they are included in several Federal statutes such as the Archeological Resources Protection Act of 1979 (16 USC 470aa-470ll) and the Federal Land Management Policy Act of 1976 (43 USC 1701 *et seq.*).

C.4.10.2 Cultural Resources Protection Procedures

Federal agencies protect cultural resources through compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, which is implemented through regulations contained in 36 CFR 800. These regulations require Federal agencies to consider the existing information, undertake identification activities if the existing information is insufficient, determine whether any cultural resources contained within the agency-defined area of potential effects meet the criteria for eligibility for inclusion in the National Register of Historic Places, determine the effect of the proposed action on significant historic properties, consult with the State Historic Preservation Office (SHPO), and afford the Advisory Council on Historic Preservation (ACHP) the opportunity to comment.

To comply with 36 CFR 800, the lead federal agency defines an "area of potential effects," or project area, for the proposed action. The project area usually comprises the physical limits of disturbance or alteration that will result from the proposed actions, such as construction, demolition, staging, or operation of a facility.

The next step in the process is to identify the presence of absence of historic properties within the area of potential effects (36 CFR 800.4). An "historic property" is an archeological site, standing structure, or traditional cultural property that is listed or is potentially eligible for listing on the National Register of Historic Places (NRHP) (36 CFR 60). Identificational studies can comprise a variety of site-specific archaeological, architectural, or cultural surveys of the undertaking's project area. Other studies may be conducted in order to evaluate an identified resource's eligibility for inclusion on NRHP.

If no cultural resources eligible or potentially eligible for the NRHP are identified during these studies, then, given the concurrence of the SHPO, the project will have no effect on historic properties and the undertaking may proceed. If historic properties are identified within the project area, then the agency in consultation with the SHPO must apply the "criteria or effect and adverse effect" as defined in 36 CFR 800.5 and 800.9.

An undertaking is considered to have an adverse effect when the effect on a historic property may diminish the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects on historic properties include, but are not limited to:

- Physical destruction, damage, or alteration to all or part of the property
- Isolation of the property from or alteration to the character of the property's setting when that character contributes to the property's qualification for the National Register
- Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting
- Neglect of a property resulting in its deterioration or destruction
- Transfer, lease, or sale of the property (36 CFR 800.9.b.1-5)

C.4.10.3 Consideration of Cultural Resources Impacts in the WM PEIS

Given the various levels of cultural resource information (the number of recorded resources and the size of surveyed areas) associated with DOE facilities across the country and the cultural resource diversity known or presumed to be located at these sites, the specific analysis of impacts must be left to site-specific or project-level NEPA documents. In addition, the locations of the different waste management activities at individual sites have not been identified. Thus, at the programmatic level, both the specific area of potential effects and the presence or absence of National Register eligible historic properties are at present unknown. Therefore, evaluation of potential impacts in this PEIS was limited to providing relevant information on existing cultural resources identified at the sites (see Chapter 4, Affected Environment) and an estimate of the extent to which potential new site surveys would be required (see the Cultural Impacts sections in the waste-type Chapters 6–10).

Appendix C
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Appendix D

Waste Management Facility Human Health Risk Estimates

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Acronyms and Abbreviations

The following is a list of acronyms and abbreviations (including units of measure) used in this appendix.

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AEDE	annual effective dose equivalent
ALARA	as low as reasonably achievable
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory-East
ANL-W	Argonne National Laboratory-West
ANSI	American National Standards Institute
BNL	Brookhaven National Laboratory
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	cancer fatality
CFR	*Code of Federal Regulations* (indicating citation from)
CH	contact-handled
CI	cancer incidence
C&OF	construction and operational fatalities
D&D	decontamination and decommissioning
DITTY	the Dose-in-Ten-Thousand-Years computational model
DOE	U.S. Department of Energy
DUST	Disposal Unit Source Term computational model
EDE	effective dose equivalent
EI	exposure index
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
ETEC	Energy Technology Engineering Center
FEMP	Fernald Environmental Management Project
Fermi	Fermi National Accelerator Laboratory
FTE	full-time equivalent
GENII	Generation II of the Hanford Environmental Radiation Dosimetry Software System
GENII-S	Sensitivity and Uncertainty Analysis portion of the GENII computational model
GTCC-LLW	greater-than-Class-C low-level waste
Hanford	Hanford Site
HEAST	Health Effects Assessment Summary Tables

HI	hazard index
HLW	high-level waste
HW	hazardous waste
ICRP	International Commission on Radiological Protection
IDLH	immediately dangerous to life and health
INEL	Idaho National Engineering Laboratory
INEXPLC	computational model for simulating close-in atmospheric dispersion, explosive releases, and particle deposition
IRIS	Integrated Risk Information System
ISC2	Industrial Source Complex Dispersion Models, Version 2
ITRI	Inhalation Toxicology Research Institute
K-25	Oak Ridge K-25 Site
KAPL-K	Knolls Atomic Power Laboratory–Kesselring
KCP	Kansas City Plant
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LDRs	land disposal restrictions
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MEI	maximally exposed individual
MEL	maximally exposed lifetime of the hypothetical farm family
MEPAS	Multimedia Environmental Pollutant Assessment System
NAS	National Academy of Sciences
NAS/NRC	National Academy of Sciences/National Research Council
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commision
NRF	Naval Reactor Facility
NTS	Nevada Test Site
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
Pantex	Pantex Plant
PCB	polychlorinated biphenyl
PEIS	DOE *Draft Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*
PGDP	Paducah Gaseous Diffusion Plant
Pinellas	Pinellas Plant
PNNL	Battelle Pacific Northwest National Laboratory
PORTS	Portsmouth Gaseous Diffusion Plant
PRESTO	series of computational models for assessing the potential human health impacts from the disposal of low-level waste

RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RH	remote-handled
SNL-CA	Sandia National Laboratory (California)
SNL-NM	Sandia National Laboratories (New Mexico)
SRS	Savannah River Site
TLV	threshold limit value
TRUPACT II	Transuranic Package Transporter–II
TRUW	transuranic waste
TWA–TLV	time-weighted average threshold limit value
UofMO	University of Missouri (Columbia)
WIPP	Waste Isolation Pilot Plant
WIPP–WAC	Waste Isolation Pilot Plant Waste Acceptance Criteria
WM	of or pertaining to the DOE Waste Management Program
WVDP	West Valley Demonstration Project
Y-12	Oak Ridge Y-12 Plant

Abbreviations

Am	americium
C	carbon
Ci	curie(s)
Cm	curium
cm^2	square centimeter(s)
cm^3	cubic centimeter(s)
Co	cobalt
Cs	cesium
d	day(s)
E	east
ENE	east-northeast
ESE	east-southeast
Fed. Reg.	*Federal Register* (indicating citation from)
ft^3	cubic foot (feet)
g	gram(s)
gal	gallon(s)
h	hour(s)
H–3	tritium

I	iodine
in.	inch
K_d	sorption distribution coefficient (for contaminants in soil)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mi	mile(s)
min	minute(s)
mph	mile(s) per hour
mrem	milliroentgen equivalent man
N	north
nCi	nanocurie(s)
NE	northeast
NNE	north-northeast
NNW	north-northwest
Np	neptunium
NW	northwest
P	phosphorus
pCi	picocurie(s)
Pu	plutonium
qt	quart(s)
rem	roentgen equivalent man
RfC	reference concentration
RfD	reference dose
Ru	ruthenium
S	south
S	sulfur
SE	southeast
Sr	strontium
SSE	south-southeast
SSW	south-southwest
SW	southwest
t	ton(s)
Tc	technetium
Th	thorium
U	uranium

W	west
WNW	west-northwest
WSW	west-southwest
Y	yttrium
yr	year(s)
yd	yard(s)

APPENDIX D
Waste Management Facility Human Health Risk Estimates

D.1 Introduction

This appendix summarizes the human health impacts posed by stationary sources of waste at U.S. Department of Energy (DOE) waste management facilities. The term "stationary source" refers to facilities that process, store, or dispose of various types of waste throughout the DOE complex, in contrast to waste transport. Waste transportation risks are discussed in Appendix E. Supplemental details of this human health risk assessment are available in a separate technical report (ORNL, 1996).

This appendix is organized as follows:

- Section D.1 defines the purpose and scope of the Waste Management (WM) Program human health risk evaluation including an overview of the five DOE WM Program waste types and waste consolidation alternatives.
- Section D.2 presents general information on the risk assessment process, including a discussion of the potentially exposed populations and health effects evaluated, assumptions used to calculate the risks to the affected populations and individuals, explanations of certain risk calculations, and directions on how to read and interpret the risk results that are presented in Section D.3.
- Section D.3 contains the human health risk evaluations for the five DOE WM Program waste types. It provides definitions of the wastes; identifies the waste consolidation alternatives evaluated; discusses the assumptions used in estimating the human health risks for routine waste management activities and potential accidents by waste type; presents a summary of the human health risk results for routine waste management activities and (where applicable) accidents by waste type; and identifies the waste consolidation options and contaminants that potentially pose the greatest and least risks to human health.
- Section D.4 describes the uncertainties associated with the waste management human health risk evaluation.
- Section D.5 presents a discussion of the mathematical models used to develop the human health risk estimates for this study.

A summary narrative explaining the health risk analysis methodologies for the reader interested in less technical information is presented in the Summary and in Chapter 5 of Volume I. Summarized results of

the risk analyses for each of the five waste types are presented in the Summary and in Chapters 6–10 of Volume I.

D.1.1 Purpose of the Waste Management Human Health Risk Evaluation

The purpose of this human health risk evaluation is to provide projections of the health risks posed by the waste consolidation options being considered for DOE waste management facilities in this draft programmatic environmental impact statement (hereinafter called the PEIS). This information, in conjunction with other PEIS impacts (e.g., transportation risks, ecological risks, air, water, and socioeconomic impacts) and costs, is intended to aid in determining the advantages and disadvantages of the various waste consolidation options.

The risk estimates presented here are based on various assumptions, best available data, and data generated by fate and transport and exposure modeling (instead of data gathered by monitoring). This was necessary because monitored data were not consistently available for all sites and/or processes have not been demonstrated fully. To maintain consistency with current regulatory approaches to risk assessment, the methodologies used to estimate the various elements of risk for the PEIS were partially adapted from existing accepted risk assessment methods (NAS, 1983; EPA, 1989a, 1991a,b; ICRP, 1977, 1979, 1990) or developed specifically for the PEIS (ORNL, 1995a-c). While it is important to recognize the purpose and limitations of this assessment, the same assumptions and methodologies were applied uniformly to all sites. Therefore, when used on a *comparative* basis at the program level, these results should provide a relatively accurate overview of the risks posed by WM Program treatment, storage, and disposal activities. More detailed risk estimates for a particular DOE site should be performed when necessary in site-specific documents (e.g., environmental impact statements, environmental assessments, risk assessments).

D.1.2 Waste Types Evaluated

Both existing and future waste management facilities were evaluated for the following waste types:

- High-level waste (HLW) (Section D.3.1)
- Low-level waste (LLW) (Section D.3.2)
- Hazardous waste (HW) (Section D.3.3)

- Transuranic waste (TRUW) (Section D.3.4)
- Low-level mixed waste (LLMW) (Section D.3.5)

The risk analysis for each waste type and site was performed based on data including (1) estimated rates of contaminant release to the air and/or the water in the water table (called "groundwater"), and (2) estimated waste processing rates (which determine a worker's hourly exposure). These two types of release rates are called "source terms." The source terms for the human health risk analysis were developed by Argonne National Laboratory (ANL) based on waste inventory information and characterization data, waste management module characterization information, and the definitions of the various PEIS alternatives. This process, as well as the source terms used in the analysis, are included in Appendix C and supporting technical reports by ANL (ANL, 1995a-e).

Health effects were not evaluated for spent nuclear fuel (from which HLW is derived) because its programmatic issues are assessed in a separate environmental impact statement (see further discussion of this in Chapter 1 of the PEIS). It is assumed that privatizing DOE treatment and disposal would produce essentially the same health effects, if the facilities are near or are in similar locations to those analyzed in this document.

D.1.3 Waste Consolidation Alternatives

For each of the waste types listed in Section D.1.2, the Oak Ridge National Laboratory (ORNL) estimated the potential health effects posed by up to four general alternatives for consolidating, processing, storing, and disposing of wastes:

- No Action: Wastes are processed and/or disposed at each site using existing or approved facilities (an approved facility is one for which National Environmental Policy Act [NEPA] review has been completed, appropriate permits received, and the decision made to proceed with the facility).
- Decentralized: Wastes are processed and/or disposed at the site where they were generated.
- Regionalized: Wastes are consolidated for processing and/or disposal at regional sites.
- Centralized: Wastes are consolidated for processing and/or disposal at one or two sites.

Within each type of alternative, there were often several potentially feasible waste management options. For example, a spectrum of Regionalized Alternatives was considered for contact-handled TRUW in which

wastes are treated and stored at as many as 10 or as few as 3 sites. The rationale for selecting these alternatives is discussed in Chapter 3.

The waste processing and disposal period for the No Action Alternatives was assumed to be 20 years. For the remaining alternatives except for HLW, it was assumed that 10 years would be needed for the construction of required waste management facilities and 10 years would be required for waste processing and disposal. The risk analysis for HLW differed in that only interim storage pending final disposal was assessed because a treatment method has already been selected and is being performed at some sites.

Many DOE sites do not currently have facilities for waste management. In the alternatives evaluation, it was necessary to assume that these sites would construct the waste management facilities required under the alternative being evaluated, and that waste processing would begin after construction was completed.

The waste disposal evaluation assessed disposal only for the sites currently storing waste. It did not include federal facilities planned for waste disposal such as Yucca Mountain because these sites will be addressed in site-specific NEPA reviews (for more information on this subject, see Chapter 2).

D.2 Evaluating the Risks Associated With Waste Management Activities

This section presents a brief introduction to the concepts and methods used to perform the human health risk analysis for the PEIS including information on the potentially exposed human populations, the means by which people could be exposed to WM Program wastes, the health effects that could result from exposure to the various wastes, and an overview of the process of estimating human health risks. In addition, this section contains a discussion of how to read and interpret the risk analysis results presented in Section D.3.

Risk analysis entails several steps including characterizing the environmental setting of the site being studied; identifying potential receptors, environmental transport pathways, and exposure routes; identifying potential human health effects to be evaluated; quantifying contaminant intakes, doses, and exposures; and calculating risks. For more detailed information on the risk analysis process used in this study, see the ORNL risk methodologies (ORNL, 1995a-c).

D.2.1 CHARACTERIZING THE ENVIRONMENTAL SETTING

The first step in estimating risk is to collect information about the site's environmental setting including agricultural data (e.g., prevalent livestock and crops, crop yields), geographical location, climatological information (e.g., annual rainfall, storm frequency, temperature range, joint frequency distribution for wind), and land use on and around the site. The environmental setting information used in the PEIS can be found in the ORNL site description report (ORNL, 1995d).

D.2.2 IDENTIFYING POTENTIALLY EXPOSED POPULATIONS

The next step is to identify the categories of people (called "receptors" in the analysis) who might be exposed to or affected by waste management processes. The receptor categories below were selected (1) to represent the populations that would most likely be exposed to contaminants during waste management activities or (2) as receptors potentially receiving the greatest exposure for the risk analysis. Health risks were not evaluated for persons who may drink water supplied from contaminated surface water or who derive a portion of their food supply from plants and animals that obtain water from contaminated surface water bodies.

- Offsite (general public) population: The offsite population within an 80-km (50-mi) radius of each site.
- Noninvolved workers: Onsite employees not directly involved in a site's waste handling activities.
- Maximally exposed individual (MEI) of the offsite population.
- MEI of the noninvolved worker population.
- Waste management workers: Onsite employees working in a site's waste management facilities, including both the workers directly involved in the waste management process and the construction workers who build the waste management facilities.
- Hypothetical farm family: An imaginary family of two adults and two children assumed to live 300 m (approximately 330 yd) downgradient of the center of a waste disposal facility in a period when institutional controls (fences, warning signs, etc.) no longer exist. The farm family engages in farming activities such as growing and consuming their own crops and livestock, and uses groundwater for drinking and for watering the crops and animals.
- Hypothetical intruder: An imaginary adult who drills a well directly through a waste disposal facility down to the water table (groundwater), brings the contaminated soil from within the disposal facility to the surface during drilling, and mixes the contaminated soil into the top 15 cm (5.9 in.) of surface soil of a 2,500-m^2 (0.6-acre) plot of land. The intruder then farms this plot and feeds him- or herself

with the crops. The intrusion scenario takes place in a period when institutional controls no longer exist.

Estimates of the offsite population and distribution within an 80-km radius of each site were obtained from the 1990 U.S. census. The population and distribution of noninvolved workers at each site were estimated based on site records, site maps, and best judgment. Because of lack of information, it was necessary at some sites to simply assume an even distribution of workers in all directions around a facility. The offsite and noninvolved worker population size and distribution for each site and the location of each site's MEIs can be found in the ORNL site description report (ORNL, 1995d).

Risks to the offsite and noninvolved worker populations were assumed to result from exposure to airborne contaminants, and were estimated only for the first 70 years after an alternative is implemented (i.e., for the lifetime of a person living during the period when treatment and storage activities take place).

The greatest risk estimates to an individual member of the offsite and noninvolved worker populations was assessed by considering the MEI in each population. In these scenarios, the MEI receives the highest total chemical intake and/or radiation dose for all exposure routes (e.g., inhalation, ingestion, direct exposure) over the person's lifetime. In considering the results of the TRUW and LLMW alternatives, note that for each *site* the MEI is one individual; however, for each *alternative* (in which the impacts from all relevant sites are considered together), the MEI is a composite of the greatest exposure to radionuclides and carcinogenic and noncarcinogenic chemicals.

The hypothetical farm family and hypothetical intruder represent two most-conservative exposure situations that occur at a time when institutional controls (fences, warning signs, land records, etc.) no longer exist, and are analyzed to determine upper-bound exposures only. The farm family is assumed to set up residence 300 m downgradient from the center of the disposal facility. The 300-m distance was chosen to ensure that the farm family's groundwater well was beyond the boundary of the disposal site (no matter what type of disposal facility is assumed for a particular site).

Risks to the hypothetical onsite farm family are evaluated for 143 consecutive 70-year lifetimes (i.e., 10,000 years) in order to determine the upper bound of long-term risks from exposure to groundwater that has been contaminated by the failure of a waste disposal facility. The maximum exposure would presumably occur in the future when the peak concentration of contaminant(s) passes the farm family's well, and might

be significant over a series of lifetimes. The 10,000-year time period was selected for the analysis in order to maintain consistency with current performance assessments and the *Guidelines for Radiological Performance Assessment of DOE Low-Level Radioactive Waste Disposal Sites* (Case and Otis, 1988). To provide some perspective on the timing of health risks predicted to result from disposal, the risk analysis identifies the 70-year lifetime (out of the 143 lifetimes evaluated) during which the highest exposures, hence, risks, are estimated to occur for the hypothetical farm family. This peak-risk lifetime is referred to in the results as the maximally exposed lifetime (MEL) of the farm family.

The intruder scenario involves chronic exposure of an individual to contaminated material brought up to the ground surface by drilling a well directly through a waste disposal facility (following guidance on intruder scenarios presented in *Intruder Scenarios for Site-Specific Low-Level Radioactive Waste Classification* [Kennedy and Peloquin, 1988]). The intruder scenario is intended to show the most conservative risk from the disposal technology itself; therefore, only the health effects from direct exposure to contaminated drilling wastes (as opposed to additional exposure to other contaminated media such as groundwater) are evaluated for this scenario. Exposure to an intruder is evaluated for one lifetime for two instances of intrusion: one at 100 years after closure of the disposal facility and one at 300 years after closure.

Worker risks are estimated both for short-term construction activities and for longer term facility operation activities. Worker activities are expected to occur over 10 to 20 years, depending on waste type and alternative, so worker risk is estimated to be a factor only during the first lifetime, or 70 years, after implementation of an alternative. The number of waste management workers involved in the various alternatives was determined as described in Section D.2.7.2.

D.2.2.1 Populations Not Specifically Evaluated

The human health risk analysis did not explicitly include risks to sensitive subpopulations (as defined by the U.S. Environmental Protection Agency [EPA] [EPA, 1989a]) such as children, the elderly, or pregnant or nursing women; however, sensitive subpopulations were considered in the development of the toxicity and exposure values that were used in the analysis, hence, are indirectly included.

For radiological exposures, the nominal risk probability coefficients (referred to as "risk factors") used to estimate the risk of cancer and adverse genetic effects from radionuclide exposures are taken from Volume 60 of the proceedings of the International Commission on Radiological Protection (ICRP), which is referred to as *ICRP 60* (ICRP, 1990). *ICRP 60* states that "[a]lthough there are differences between the sexes and between populations of different age-specific mortality rates, these differences are not so large as to necessitate the use of different nominal probability coefficients." A small difference exists, however, between the risk factors used for workers and those used for the population as a whole. This difference arises principally because the more sensitive younger age groups and pregnant women are included in the whole population (as opposed to the worker population). With regard to the elderly, the radiological risks presented in the PEIS were calculated as the estimated risks a person would sustain over a 70-year lifespan assuming 50 years of radionuclide uptake and commitment (the concept of radionuclide commitment is explained in Section D.2.6). A person who is already elderly when a PEIS alternative is implemented would not likely be exposed for the entire 50 years. Therefore, the use of a 50-year uptake and commitment period should lead to an overestimate of the risks to the elderly. This overestimate would be more pronounced in populations containing a disproportionate number of elderly people.

The EPA slope factors and reference doses (RfDs) or reference concentrations (RfCs) used to evaluate risks from exposures to chemicals are similarly conservative. Slope factors and RfDs or RfCs are generally extrapolated from animal data and include what is termed an "uncertainty factor." This uncertainty factor is an attempt to arithmetically express how well or poorly the pharmacokinetic differences between animals and humans are understood for a particular chemical; it also accounts for the effects of the chemical on various human subpopulations. As such, these slope factors and RfDs or RfCs are considered valid for a wide range of human subpopulations. For more information on this subject, readers may wish to refer to the EPA sources for toxicity factors, the Health Effects Assessment Summary Tables (referred to as HEAST) and the on-line Integrated Risk Information System (called IRIS).

Executive Order 12898 on environmental justice mandates adding the dimension of minority and low-income populations to research, data collection, and analysis to the extent practicable and appropriate. Certain Native American and minority or low-income populations might consume larger quantities of locally grown produce or fish from local water sources than the population as a whole; this situation might result in higher risks to these particular people.

DOE has not evaluated the human health risk to subpopulations that may derive a substantial portion of their food supply from native plants and animals that live near the DOE sites. The results of such a complex analysis would likely vary widely both within and among sites, depending on the assumptions used for parameters such as locations of waste management facilities on the sites, routes of exposure, and dietary habits. Thus, the results would not help to clarify programmatic decisions. The risk to human health from ingesting native plants and animals cannot be fully analyzed with confidence until the locations of facilities on the sites are known, the routes of exposure are explicitly defined, and the dietary habits of affected subpopulations are quantified. Therefore, analysis of health effects from subsistence consumption of fish, wildlife, and native plant species is not included in the WM PEIS but may be considered in subsequent sitewide or project-specific NEPA documents if the appropriate information is available.

D.2.3 Identifying Environmental Transport Pathways

The next step in the risk analysis process is to identify the pathways between the sources of contamination and the individuals or populations at risk. These pathways are the actual physical routes along which the contaminants would travel from the source to the exposed individual or population.

Waste management workers working at waste management facilities can come into direct contact with wastes and/or waste containers and with intrafacility airborne contamination during routine treatment, storage, and disposal operations, and during accidents. The remaining receptors become exposed only if contaminants are released from the waste management facility to environmental media such as air or groundwater. For the purposes of the PEIS, it is assumed that contaminants are released (1) to the air during waste treatment operations and accidents, (2) to the groundwater at some point after wastes have been disposed of in engineered disposal facilities, and (3) to the surrounding soil upon intrusion into disposal facilities following institutional control. During treatment operations and accidents, area winds carry released contaminants from the treatment facility toward the offsite and noninvolved worker populations. These airborne contaminants can be inhaled as well as deposited on plants and soil. Wind also transports the contaminated soil that the intruder brings to the surface during drilling and mixes into his/her farm plot. In the waste disposal scenarios, it is assumed that contaminants leach from the facility to the groundwater and are transported downgradient toward the hypothetical farm family's drinking water well.

D.2.3.1 Transport Pathways Not Evaluated

DOE has not evaluated the human health risk to persons who may drink water supplied from contaminated surface water or who derive a portion of their food supply from plants and animals that obtain water from surface water bodies. This is a complex analysis that cannot be performed with confidence until the locations of the facilities on the sites are known and the routes of exposure explicitly defined. Therefore, analysis of health effects from the surface water pathway is not included in the WM PEIS but may be considered in subsequent sitewide or project-specific NEPA documents. A limited analysis was performed to show the potential health effects from the deposition of airborne contaminants on surface water bodies.

Deposition of Radionuclides Onto Surface Water with Subsequent Ingestion. The deposition of contaminants by an airborne plume on an exposed body of water was eliminated as a pathway from detailed quantitative analysis. Preliminary tests were performed to determine the order-of-magnitude impacts of this secondary exposure pathway. These tests, which involved varying rates of flow of surface water, widths of surface water bodies, and distances from the atmospheric source to the receptor, demonstrated that the contribution of this secondary pathway to the final dose was at least 3 orders of magnitude smaller than the dose resulting from inhalation of the plume. Tests were performed for a hypothetical unit release and atmospheric deposition of several representative radionuclides using parameters associated with the Columbia River near Hanford (Washington) and the Clinch River near ORNL (Tennessee). The Columbia has an average width of 457.2 m, an average depth of 6.1 m, and an average flow speed of 1.2 m/s. The Clinch River has an average width of 124.3 m, an average depth of 9.1 m, and an average flow speed of 0.1 m/s. For the test, the atmospheric source was located at three different distances from both rivers: 10 m, 300 m, and 16.1 km. The receptor was located at the river and drank 1 L (0.9 qt) of contaminated water per day. The cancer incidence risk from inhalation of the plume is compared with the cancer incidence risk from ingestion of the contaminated water. Table D.2–1 summarizes the results for uranium–238.

Deposition of Chemicals Onto Surface Water With Subsequent Ingestion. Tests were performed for exposure to unit releases of chemicals for some of the same scenarios outlined above. Benzene and 1,1,1-trichloroethane were chosen because both are in the PEIS source terms (Table D.2–2). Benzene is a carcinogen for inhalation and ingestion, and 1,1,1-trichloroethane is a noncarcinogen for inhalation and ingestion. Chemicals that exhibit carcinogenicity for ingestion but not for inhalation (or vice versa) were not examined because an accurate comparison could not be made.

Table D.2–1. Preliminary Surface Water Analysis Results for Radionuclides

Contaminant: Uranium–238				
River	Distance (m)	Ingestion Cancer Incidence Risk	Inhalation Cancer Incidence Risk	Approximate Difference[a]
Columbia	10	2.4E–11	4.9E–01	10 orders of magnitude
	300	5.3E–13	3.6E–04	9 orders of magnitude
	16,100	7.7E–15	9.5E–08	7 orders of magnitude
Clinch	10	3.4E–12	3.6E–04	8 orders of magnitude
	300	7.7E–11	2.4E–01	10 orders of magnitude
	16,100	1.0E–13	1.9E–07	6 orders of magnitude

[a] Difference (in orders of magnitude) between cancer incidence risks for ingestion versus inhalation.

Table D.2–2. Preliminary Surface Water Analysis Results for Chemicals

Columbia River at 300 m					
Contaminant	Ingestion Hazard Quotient	Inhalation Hazard Quotient	Ingestion Cancer Incidence Risk	Inhalation Cancer Incidence Risk	Approximate Difference[a]
Benzene	--	--	7.5E–19	8.7E–10	9 orders of magnitude
1,1,1-Trichloroethane	1.4E–14	7.8E–06	--	--	8 orders of magnitude

[a] Difference (in orders of magnitude) between hazard indices and cancer incidence risks for ingestion versus inhalation.

D.2.4 IDENTIFYING LIKELY EXPOSURE ROUTES FOR POPULATIONS AND INDIVIDUALS

The following sections describe the exposure routes by which the various receptors may come into contact with radiological and chemical contaminants. These exposure routes are illustrated in Figures D.2–1 through D.2–4.

D.2.4.1 Offsite and Noninvolved Worker Population Exposure Routes

It was assumed that the offsite population could be exposed to radionuclides, carcinogenic chemicals, and noncarcinogenic toxic chemicals by coming into contact with contaminated air. Airborne contaminants can be inhaled, taken up by agricultural animals and plants and subsequently ingested, or can cause direct (external) exposure via immersion in a plume of contaminated air or exposure to contaminated soil. Noninvolved workers were assumed to be exposed only to atmospheric releases, because institutional controls should ensure that this population is not exposed to contaminated groundwater or surface water through drinking or showering.

The offsite and noninvolved worker populations were evaluated for dermal exposure to tritium derived from tritiated water in the atmosphere. Both absorption through the skin and the lungs were taken into account; this combined rate of absorption was assumed to be 150% of the inhalation intake rate alone (Napier et al., 1988).

D.2.4.2 Hypothetical Farm Family Exposure Routes

The risks to the hypothetical farm family were analyzed only for the waste types that will be disposed of in DOE facilities (e.g., LLW and LLMW). It was assumed that the farm family could be exposed directly and indirectly to groundwater contaminated by a release from the disposal facility. Shallow land disposal facilities were assumed to allow immediate releases; tumulus and below-ground vault disposal facilities were assumed to fail and allow release in 300 and 750 years, respectively. The exposure routes evaluated for the farm family include ingestion of contaminated groundwater and ingestion of crops and animals contaminated by exposure to groundwater.

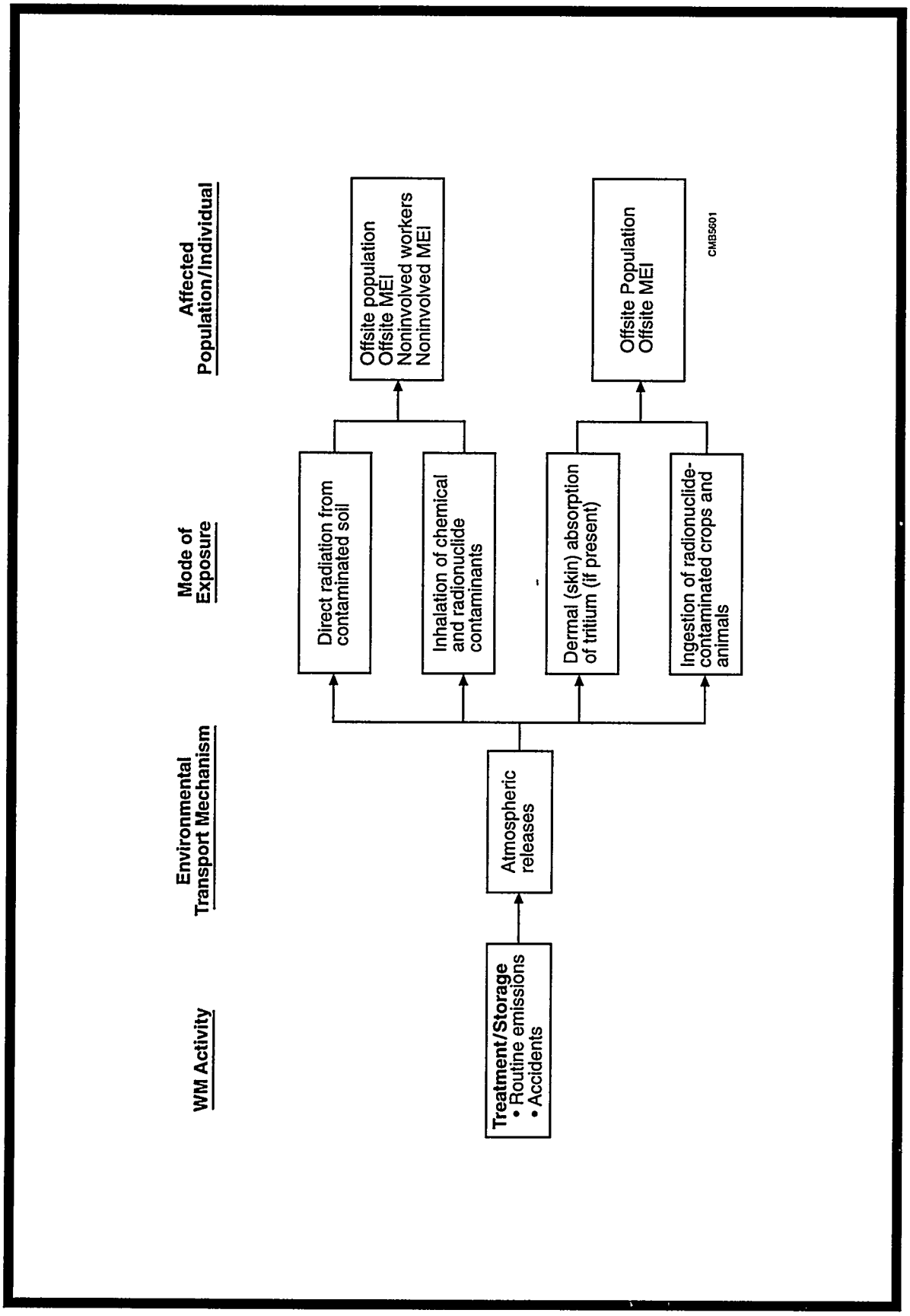


Figure D.2-1. Exposure Routes for the Offsite and Noninvolved Worker Populations for Treatment and Storage Activities

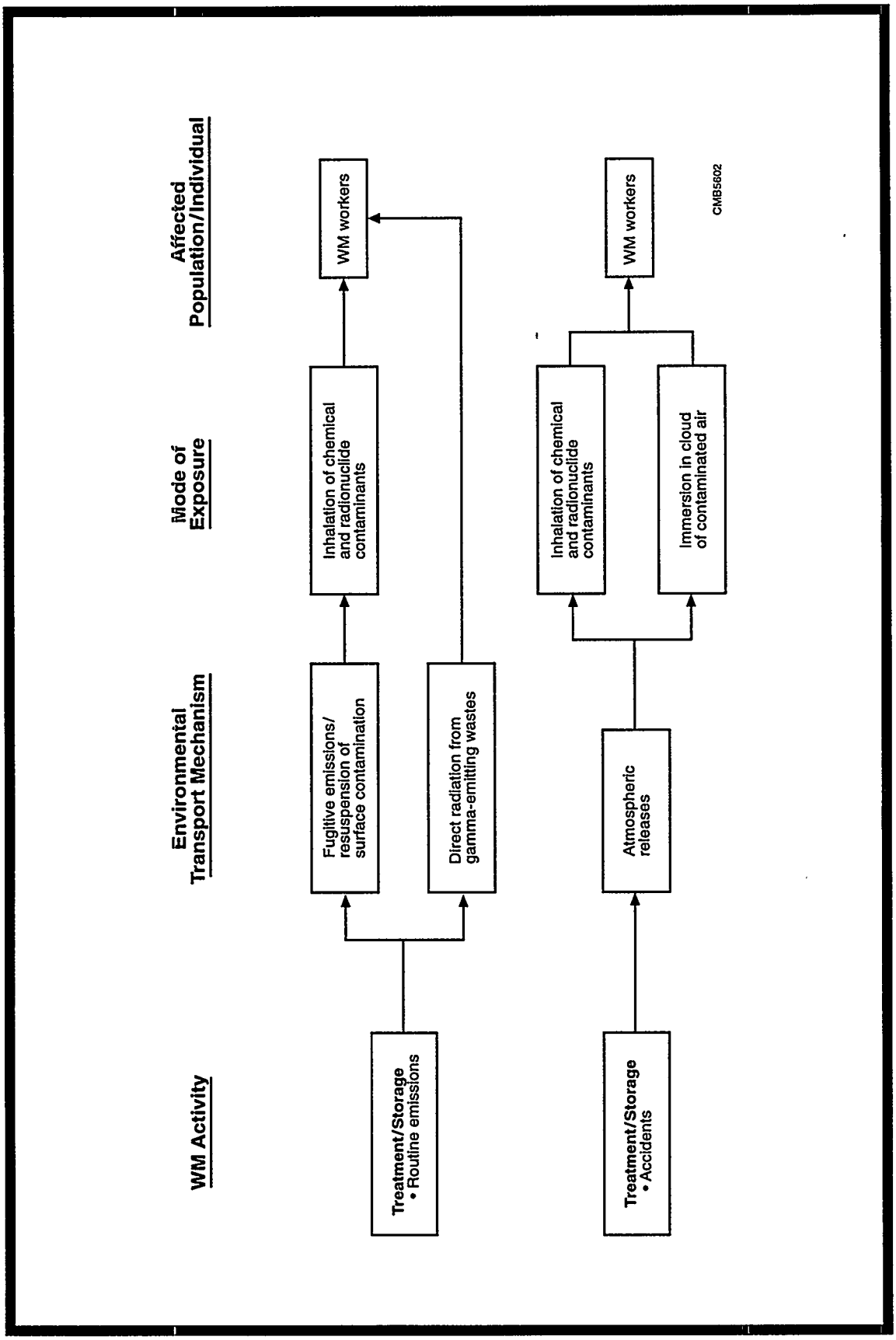


Figure D.2-2. Exposure Routes for Waste Management Workers for Routine Operations and Accidents During Waste Treatment and Storage

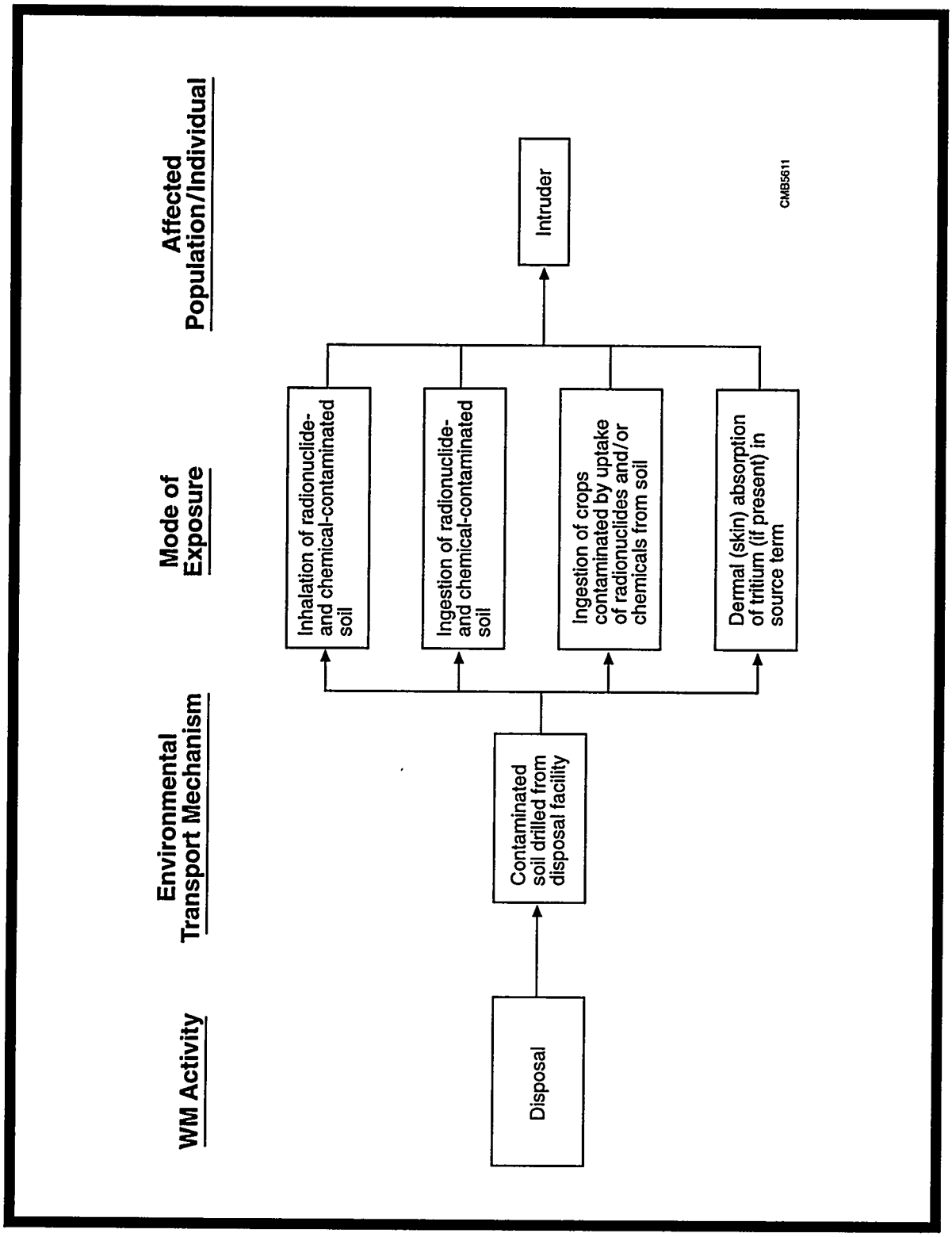


Figure D.2–3. Exposure Routes for the Intruder for Disposal Activities

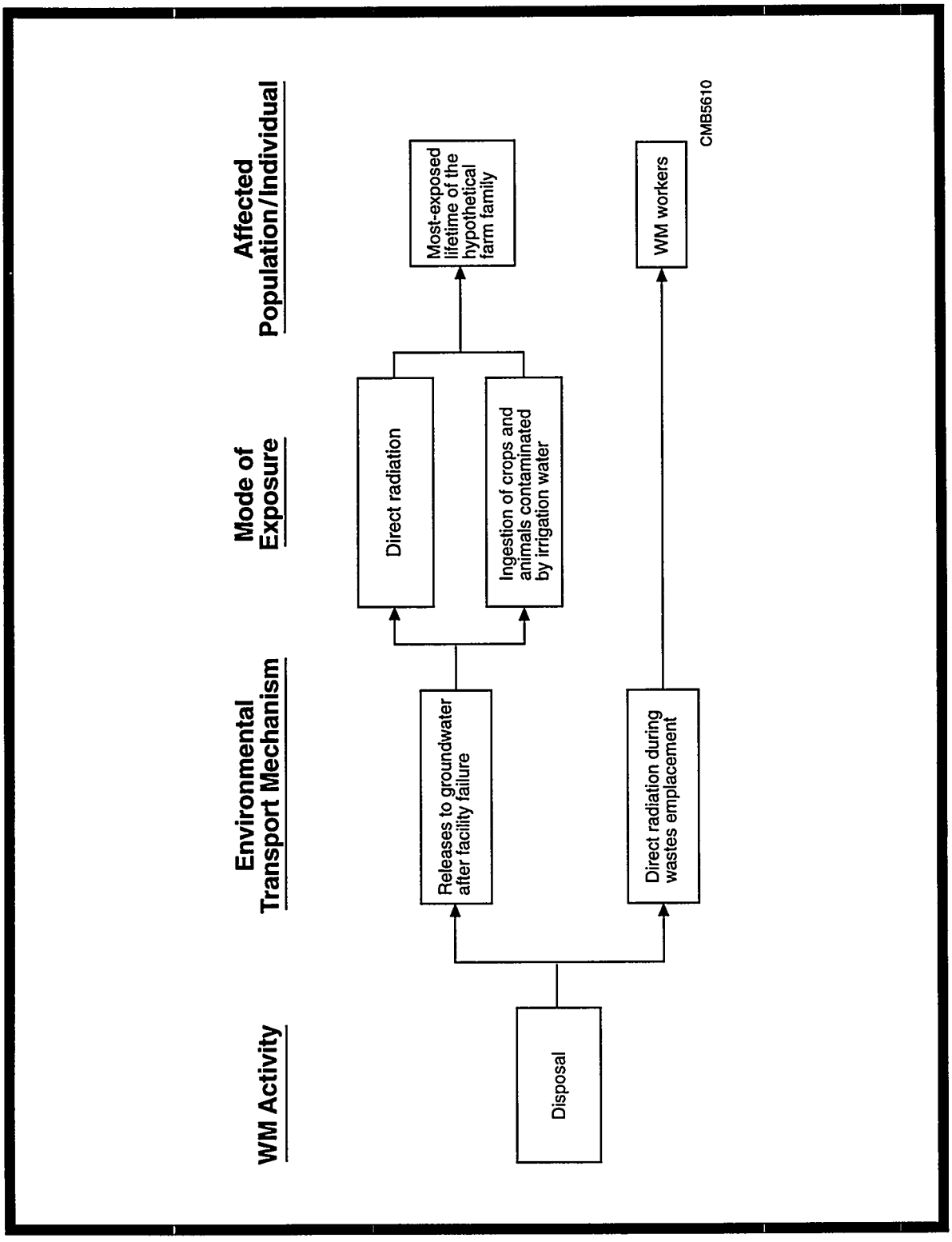


Figure D.2–4. Exposure Routes for the Farm Family and Waste Management Workers for Disposal Activities

D.2.4.3 Hypothetical Intruder Exposure Routes

Exposure of the intruder was assessed only for LLW and LLMW, the waste types that will be disposed of in DOE facilities. The exposure routes evaluated for the intruder involve exposure to soil contaminated with radionuclides for LLW and with radionuclides and hazardous chemicals for LLMW. These exposure routes are direct radiation from the soil, ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil (for radionuclides); and ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil (for chemicals).

D.2.4.4 Worker Exposure Routes

To provide an overview of the program-level health impacts from waste treatment, storage, and disposal activities, the risks to waste management workers include the risks to workers building waste management facilities. Workers directly involved in treatment, storage, and disposal were assumed to be exposed to contaminated air in work areas resulting from fugitive treatment emissions and resuspended surface contamination on waste containers, to receive external exposure from radioactive wastes, and to be at risk of death or injury from industrial-type physical hazards. The worker exposures associated with placing wastes into disposal facilities were assessed separately from treatment risks. Construction workers were assumed to be exposed only to construction-related physical hazards, not to radiological and chemical wastes. The construction and operational risk factors used in this risk analysis are based on current statistics from the U.S. Bureau of Labor Statistics and the National Safety Council, as discussed in the PEIS unit risk methodology (ORNL, 1995c). At sites where no construction was assumed, these risks were not estimated.

D.2.5 Identifying the Human Health Effects to Be Evaluated

The PEIS focuses on certain human health impacts as one of the bases for comparing the various waste management alternatives. In this risk evaluation, it was assumed that health effects, which might range from mild clinical symptoms of chemical exposure to bodily injury, illness, or death, could result from exposure to radionuclides, carcinogenic chemicals, and noncarcinogenic toxic chemicals as a result of both routine waste management operations and potential accidents. In addition to exposure-related health problems, waste management workers were assumed to be at risk of on-the-job injuries or deaths from physical trauma

(falls, crushing, electrocution, etc.). The following health effects, called "endpoints" in the analysis, were evaluated:

- Cancer incidence from radionuclide and chemical exposures
- Cancer fatalities from radionuclide exposures only
- Adverse genetic effects caused by exposure to radionuclides
- Hazard index for nonworkers (an indicator of the likelihood of noncancer toxicity caused by continuous exposure to nonradioactive waste components)
- Exposure index for workers (an indicator of the likelihood of noncancer toxicity caused by work-day exposure to nonradioactive waste components)
- Waste management worker fatalities and injuries associated with the construction and operation of waste management facilities

In addition, in the accident scenarios, an "immediately-dangerous-to-life-and-health (IDLH) index" was calculated for workers as an indicator of the likelihood that contaminant levels might impair escape or be immediately dangerous to life and health.

For the purposes of this evaluation, the concepts of cancer incidence and cancer fatality refer to what are termed "excess cancers," i.e., cancers that would not otherwise have occurred. These terms encompass all types of cancer and any occurrence(s) of cancer over the 70-year lifetime of an individual.

Radiation-Related Health Effects. It was assumed that exposures to radiation can result in cancer incidence, cancer fatality, and adverse genetic effects. Adverse genetic effects include gene mutations (alterations in the elementary units of heredity, the genes) and gross chromosomal aberrations (changes in the structure or number of chromosomes). Because exposure to contaminants in and from DOE sites might occur over many generations, concern exists that the cumulative genetic damage carried benignly across generations might, at some point, produce disease that is not accounted for in the basic cancer risk calculations.

The frequency with which these three health effects occur was assumed to be directly proportional to the amount of radiation absorbed by the receptor (see the discussions on "effective dose equivalent" and dose "commitment" in Section D.2.6). Moreover, these impacts were assumed to occur in a fixed ratio to one another. For example, for all receptors except waste management workers, the ratio of cancer incidence

to cancer fatality to genetic effects was taken to be 17:5:1 (see Section D.2.8.1 for a more detailed discussion of these assumptions).

Chemical-Related Health Effects. It was assumed that exposure to hazardous (nonradioactive) chemicals can cause cancer and/or a spectrum of toxic effects ranging from mild headaches or nasal irritation to more serious impacts such as organ (e.g., liver, kidney) toxicity, neurotoxicity, immunotoxicity, developmental toxicity, reproductive toxicity, and genetic toxicity.

The risk of cancer fatality was calculated for radionuclides but not for chemical carcinogens; this is discussed in more detail in Section D.2.6.3.

D.2.5.1 Factors Excluded From the Analysis

The risks from enhanced or diminished toxicity from interactions among components of a contaminant mixture (termed "synergy" and "antagonism," respectively), or the effects of multiple chemical forms of the same atom ("speciation") or combination of atoms ("complexing") were not evaluated because not enough information exists on these effects. If synergism or antagonism is occurring at a particular site, the risks there will be accordingly under- or overestimated. Similarly, since complexing and speciation can affect a contaminant's physicochemical and health-related properties including its toxicity, carcinogenicity, reactivity, and water solubility (hence, transportability), the lack of toxicity information on waste complexing and speciation may introduce some additional uncertainty to the risk analysis.

D.2.6 Quantifying Contaminant Intakes, Doses, and Exposures

This section presents a brief overview of how chemical and radiological exposures are measured. For more information, refer to the EPA risk assessment guidelines (EPA, 1989a) and the ORNL risk methodologies (ORNL, 1995a,b).

D.2.6.1 Quantifying Chemical Intake and Exposure

Chemical hazards are generally quantified by an individual's intake of a chemical. Intake is expressed in milligrams of contaminant ingested, inhaled, or absorbed per kilogram of body weight per day. When evaluating health effects from chemical exposure, intake values for noncarcinogenic chemicals are compared to EPA RfDs or RfCs as published in HEAST (EPA, 1992b) and IRIS (EPA, 1991c) (for all receptors except waste management workers), and intake values for chemical carcinogens are multiplied by EPA cancer slope factors (EPA, 1991c, 1992b) (for all receptors). For workers, American Conference of Government Industrial Hygienists' (ACGIH) time-weighted average threshold limit values (TWA–TLVs, or more simply, TLVs) are used rather than RfDs or RfCs, since TLVs are based on workday exposure concentrations (ACGIH, 1992).

There are many uncertainties inherent in the process of formulating RfDs and cancer slope factors. For example, a margin of safety is incorporated into these values (i.e., these values tend to overestimate the risk of the toxicant to some degree to help ensure that human health is protected). In addition, uncertainties are introduced when the findings of dose-response research performed on animals are applied to humans; findings of studies performed at high exposure levels are extrapolated to low exposure levels; results concerning acute exposures are extended to chronic exposures; and findings from occupational conditions are used to characterize toxicity in nonoccupational or environmental conditions.

The magnitude of these uncertainties is not well known; estimates from different studies vary depending upon factors such as the number of studies performed for a particular substance and the receptors and scenarios for which the substance was investigated.

D.2.6.2 Quantifying Radiological Dose and Exposure

A variety of units are used to indicate the amount, intensity, and potential health effects of radiation. The "curie" (abbreviated Ci) is a measure of the amount of radioactive decay occurring in a sample of radioactive material, and is defined as 37 billion disintegrations (individual radioactive decay events) per second. The rate of decay of 1 g of radium is the basis for this unit of measure. Amounts of radionuclides are commonly measured in curies or fractions of curies such as the picocurie (pCi), which is a trillionth of a curie. Emission rates are typically measured in picocuries per year (pCi/yr), and concentrations in units such as picocuries per cubic meter (pCi/m^3) or picocuries per gram (pCi/g).

The same dose (absorbed by the human body) of different types of radiation (e.g., alpha, beta, gamma) can produce different health risk outcomes and different effects on living cells. To standardize for these effects, a unit of radiation measure called a "rem" is used as a way of measuring the biological effects of a given dose of any type of radiation. The rem has built-in factors that weight the dose according to each type of radiation's capacity for causing biological damage (this capacity is called the "biological effectiveness" of the radiation). Hence, 1 rem of one type of radiation (for example, gamma radiation) is presumed to have the same biological effects on a given type of tissue as 1 rem of any other type of radiation (say, beta radiation). This unit of measure allows comparison of the biological effects (on a given type tissue) of radionuclides that emit different types of radiation. A millirem (mrem) is one-thousandth of a rem. See the ORNL worker risk methodology (ORNL, 1995b) for a more detailed description of the different types of radiation.

The various organs of the body have different susceptibilities to harm from radiation; for example, the gonads tend to be more sensitive to radiation damage than the cornea of the eye. The unit of measure that takes these different susceptibilities into account to provide a broad indicator of the total effective radiation dose is called an "effective dose equivalent" (or "EDE"). It is obtained by multiplying the dose (or "dose equivalent") in rems in each major organ or tissue by a weighting factor associated with the risk susceptibility of the tissue or organ, then summing the totals. This unit of measure allows comparison of the general adverse consequences to people who are exposed to radiation, regardless of the different susceptibilities of individual types of tissue in different organs to such exposure. For a more detailed discussion of organic and tissue weighting factors, see the ORNL worker risk methodology (ORNL, 1995b).

Three types of radiation doses are calculated in the PEIS: an external dose, an internal dose, and a combined external and internal dose (or total dose). External doses are from sources located outside the body such as a sealed radioactive container or contaminated air, water, or soil. Internal doses arise from sources that have entered the body, usually from eating or drinking contaminated substances or breathing contaminated air.

D.2.6.3 Comparing Radionuclide Exposures to Chemical Exposures

Radionuclide and chemical exposures are, for the most part, very different from one another. A chemical contaminant may be released to groundwater or dispersed into the air, whereupon it is deposited on the ground, vegetables or other crops, or other surfaces. A person becomes exposed by inhaling the contaminant, drinking contaminated water, eating contaminated vegetables, etc. A number of chemicals, such as mercury, lead, and PCBs, bind to or "bioaccumulate" in various body tissues such as bone and fat and may continue to cause toxic effects long after initial exposure. However, quite often, a chemical that has entered the body exerts its toxic or carcinogenic effect over a relatively short period of time and is excreted or otherwise eliminated from the exposed person's body. (The time required for a living organism to eliminate half the amount of an absorbed or ingested chemical substance by natural processes is termed the "biological half-life" of that substance.)

There seems to be an exposure *threshold* for noncancer effects caused by chemicals that do not bioaccumulate. Above this threshold exposure level, these chemicals begin to exert adverse effects; below the threshold, their effects seem to be negligible. A person can be exposed many times to less than the exposure threshold of chemicals that do not bioaccumulate and show no cumulative adverse noncancer effects.

Based on the characteristics of the contaminants of concern in the WM Program waste types, it was assumed in this risk analysis that chemical contaminants of concern do not significantly bioaccumulate. Accordingly, the exposure time for toxic chemicals was assumed to equal the release time. The release time was assumed to be equal to the total processing period for the waste type in question (e.g., 10 or 20 years). While this assumption may be somewhat conservative, it is applied across all sites; hence, the *relative* ranking of sites by risk will likely remain the same.

People are exposed to radionuclides by the same mechanisms as they are to chemicals. However, radionuclides may be present in forms such as simple salts that, when ingested, can be incorporated into body tissues (such as bone) more readily than many hazardous chemicals. Radionuclides may also adhere to particles that, once inhaled, are too small for the lungs to expel. In these circumstances, a radionuclide will stay in the body and continue to deliver a radiation dose long after the exposed person has stopped ingesting or inhaling the radionuclide. (The persistence time of a radionuclide in a living organism is measured in terms of the radionuclide's "effective half-life." This is the period of time required for the

amount of radionuclide in an organism to diminish 50% from the combined action of radioactive decay and biological elimination.)

Based on the radionuclides found in the WM waste types and ICRP guidance (ICRP, 1977; 1990), it was assumed that most ingested or inhaled radionuclides remain in the body and continue to expose the person for the rest of his or her life (i.e., the internal dose continues to accumulate). In risk analysis, this continuing, cumulative internal exposure period is referred to as the "commitment period." A commitment period of 50 years was chosen for this study (ICRP, 1990). This time period reflects the average person's working lifetime beginning at age 18, and is a standard time period used in risk assessments. Accordingly, in this study, the risks from radionuclide exposure are calculated not just for the waste treatment time span (10 or 20 years, according to waste type) but as though the internal exposure period persists for a total of 50 years (this does not apply to external exposure to radiation). Therefore, the total EDE deposited in the body over the 50 years after intake of a radionuclide, called the "committed EDE," is used in the PEIS risk calculations.

Because we do not have a clear understanding of the biological processes by which chemicals and radiation cause cancer, a conservative approach (and the one adopted in the PEIS) is to assume that there is *no minimum or threshold value for exposures to carcinogens*. This means that any exposure to a carcinogen increases the lifetime risk of cancer. Consequently, it is assumed that the risk of cancer accumulates with repeated exposures to carcinogens and that the risk of cancer from multiple exposures to multiple sources is additive.

The risk of cancer fatality was calculated for radionuclides but not for chemical carcinogens. This is because research and epidemiological studies have provided enough information to develop risk factors for both cancer incidence and fatality caused by radionuclides; however, there is not yet enough information to develop risk factors for cancer deaths resulting from chemical exposures. These differences between the amounts of information available about cancers associated with chemical and radionuclide exposures have another implication: The risk of cancer incidence from exposure to hazardous chemicals is not, strictly speaking, directly comparable to the risk of cancer incidence from exposure to radionuclides (this becomes an issue only in the risk analyses for TRUW and LLMW, which contain both radionuclides and hazardous constituents). Readers should bear this in mind when assessing the risk analysis results.

D.2.7 Calculating Exposures for the PEIS Receptors

This section presents a brief introduction to the methods used to model the fate and transport of chemical and radiological contaminants between their initial release and the point at which the various receptors are exposed, and to calculate the unit chemical intakes and radiological doses the receptors receive.

For every potential contaminant in these studies, it was assumed that one unit amount of contaminant is released to various environmental media (e.g., air, soil, or groundwater); or, for worker exposures to radionuclides, is available to cause direct exposure. This unit is 1 Ci for radionuclides and 1 g for chemicals. Appropriate fate and transport models and dose assessment models were then used to estimate the exposures the various receptors sustain from this unit of contaminant. These models use information about the physical and chemical properties of the contaminants and the specific environmental setting in which the contaminants were released to calculate the direction in which the contaminants move; the rate at which they move into different environmental media (for example, air, soil, water); their dilution, dispersion, and degradation or decay; and their movement via the food chain. The models described below are discussed further in Section D.5 and in supporting ORNL technical reports (ORNL, 1995a-c).

D.2.7.1 Calculating Exposures to the Offsite and Noninvolved Populations, Hypothetical Farm Family, and Hypothetical Intruder

Regulatory Considerations for Public Receptors. While there are regulatory standards governing the maximum permissible radionuclide and chemical exposures to members of the public (i.e., to all receptors other than waste management workers), the doses to these receptors were not limited in this analysis for two reasons. First, a waste management facility is a relatively controlled environment so worker exposures are somewhat more easily monitored than exposures to the public. Second, leaving the predicted exposures to the offsite and noninvolved worker populations unmodified enables the reader to make a better assessment of the maximum risks among the various PEIS alternatives. (Applicable environmental requirements would be taken into account in the implementation of a selected alternative).

Estimating Doses From Contaminated Groundwater. For the groundwater pathway, the computer models DUST (Disposal Unit Source Term) (Sullivan, 1992), MEPAS (Multimedia Environmental Pollutant Assessment System) (Droppo et al., 1989), and DITTY (Dose in Ten Thousand Years) (derived from the GENII model) are used to simulate environmental transport of contaminants from the source (waste disposal

location) to groundwater to potential receptors. Contaminant-specific unit rate of transfer (flux) rates out of the engineered disposal facility are generated by DUST and are used by MEPAS to simulate the transport of contaminants through the vadose zone (the area above the permanent groundwater level) and into the groundwater. The MEPAS model then predicts the environmental concentration of contaminants at various receptor locations as a function of time. For radionuclides, the 70-year average concentrations from MEPAS are used by DITTY to predict the dose to receptors for each radionuclide. For hazardous chemicals, the 70-year average concentrations are multiplied by standard intake values for water and food to arrive at a contaminant-specific intake, which is multiplied by the size of the drinking water population to give the total contaminant dose for each 70-year period.

Radioactive decay and ingrowth of daughter products are taken into account at several points during the estimation of dose from the groundwater pathway. Radioactive decay that occurs prior to the disposal facility breach is calculated, and the contaminant inventory is modified accordingly. Decay that occurs after the facility breach and during transport to the vadose zone is accounted for prior to the transfer of flux rates to MEPAS. The MEPAS model then accounts for radioactive decay and ingrowth involved in transport through the vadose and saturated zones. All doses from daughter products are attributed to the parent radionuclide in the analysis results.

Estimating Radionuclide Doses From the Atmosphere. For atmospheric transport of radionuclides, doses are estimated by a program called GENII (Generation II of the Hanford Environmental Radiation Dosimetry Software System) (Napier et al., 1988). GENII contains algorithms, data, and methods for calculating radiological doses to various organs and tissues and for calculating EDEs based on ICRP guidance (ICRP, 1977, 1979). To create unit doses for the atmospheric release of radionuclides, GENII is run using an emission rate of 1 Ci per year for each radionuclide in the GENII library. The GENII program then uses the modeled atmospheric concentrations to predict the unit dose to potential receptors. A separate unit dose is generated for both an acute (i.e., 24-h) release period and a one-year release period. The unit dose calculated for acute releases is used to evaluate the accidental release scenarios. The one-year unit dose is used to project cumulative doses associated with chronic release scenarios. This is accomplished using radionuclide-specific cumulative dose conversion equations, which calculate the cumulative EDE based on the number of years of release. As previously noted, when calculating the cumulative EDE, radioactivity is assumed to be continually deposited in the body for 50 years after exposure occurs. GENII also accounts for radioactive decay and ingrowth of daughter products; all doses from daughter products are attributed to the parent in the analysis results.

Estimating Chemical Intakes From the Atmosphere. For chemicals, ISC2 dispersion models (Industrial Source Complex Dispersion Models, Version 2) (EPA, 1992a) are used to estimate exposures to contaminants. To create site-specific unit intakes for the atmospheric release of chemicals, ISC2 is run using an emission rate of 1 g/s with site-specific information for wind distribution. The ISC2 model predicts atmospheric concentrations based on this emission rate for each block in a circular grid comprising 16 directional sectors (e.g., north, north-northeast, northeast, east-northeast, etc.) at 10 radial distances out to 80 km (50 mi) from the point of release, yielding a distribution of unit atmospheric concentrations. The highest concentration in a block with actual population is used to generate the MEI's intake, while the population-weighted average concentration is used to generate the population intake. Recall that, unlike radionuclides, there is no commitment period for chemical exposures. To generate the unit intakes for chemicals, the unit air concentration predicted by ISC2 is converted to a unit intake using standard exposure parameters developed by the EPA, such as how much air an average-sized adult breathes per day (EPA, 1991a).

Estimating Doses and Intakes From Contaminated Soil for the Intruder Scenario. This estimate is based on the inventory of contaminants in the disposal facility. Contaminant concentrations in soil are derived for the intruder by (1) calculating the volume of the cylinder of soil removed from the waste facility during drilling; (2) multiplying the inventory in the disposal facility by the ratio of the well volume to the facility volume to derive the amount of contaminant removed by drilling; and (3) calculating the final concentration of contaminant in the 2,500-m^2 farm plot after the contaminated well-drilling soil is mixed into the top 15 cm of plot soil.

The exposure pathways evaluated for radionuclides are direct radiation from the soil, ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil. The exposure pathways for chemicals are ingestion of plants, inadvertent ingestion of soil, and inhalation of resuspended soil. The GENII computer model is used to calculate the 50-year cumulative EDE for radionuclide exposures. This dose is multiplied by the appropriate risk factors to calculate the resulting potential cancer fatalities, cancer incidence, and genetic effects. Radioactive decay and ingrowth of daughter products are accounted for in both intruder scenarios. An enhanced version of the PRESTO computer model (Fields et al., 1986; Fields and Mellescue, in preparation) is used to calculate the cancer incidence for carcinogenic chemicals and the hazard index for noncarcinogenic chemicals.

D.2.7.2 Calculating Exposures to Waste Management Workers

Characterizing Waste Management Facilities and Treatment Processes. Estimating worker exposures calls for characterizing the various waste management facilities and treatment processes used in each alternative. To make comparative analysis possible, these characterizations are based on the conceptual designs of "generic" waste management facilities developed by EG&G Idaho, Inc., for estimating the costs associated with the various PEIS alternatives, and on consistent assumptions about worker activities and worker protection (EG&G, 1992). Each individual process or step of treating, storing, and disposing of a waste (such as retrieving waste from current storage, receiving and inspection, shredding and compaction, incineration, solidification, interim storage, packaging, shallow land burial, and below-ground vault disposal) is identified and analyzed separately for risk as a "module." Each module serves conceptually as a self-contained "box" within which worker exposures may occur; each can contain several submodules or worker activities (see ORNL, 1995b).

Modules can be arranged to form "treatment trains" that contain all the processes required to treat, store, and dispose of a specific type of waste. A treatment train for solid LLW, for instance, might consist of size reduction (shredding), compaction, packaging, and shallow land burial. These generic modules are interchangeable and can be used as needed to formulate the treatment trains for all the different waste types in the analysis (for example, the incineration module is used in several of the treatment trains for HW, LLW, LLMW, and TRUW; and the compaction module is used in many of the treatment trains for LLW, LLMW, and TRUW).

Estimating Staffing Requirements. Once the various types of waste management facilities have been characterized, staffing requirements are then estimated. To make it possible to compare estimated worker exposures to regulatory criteria, staffing was expressed as the number of "full-time equivalents" (FTEs). An FTE was assumed to be commensurate to one individual working full-time in a waste management facility. In reality, one FTE could represent several individuals who are not exposed full-time to waste management activities, but whose *cumulative* work time totals one FTE. Because the risk of exposure could be shared by more than one worker working less than full-time in a waste management facility, risks to actual individual workers might be overestimated. When interpreting the risk analysis results, readers may find it useful to think of an FTE as a hypothetical worker or "worker equivalent." Note that radiation doses to workers are expressed in FTE-rem instead of person-rem.

The staffing requirements for facilities of various sizes were estimated using equations developed through linear regression analysis. These equations, which predict the number of FTEs needed according to facility capacity, were based on data points provided by EG&G Idaho, Inc. It was assumed that the facilities operate at 70% availability (i.e., they are not operating the other 30% of the time). Workers are assumed to be exposed by treatment or handling processes 5.6 hours/day, 240 days/year, totaling 1,344 hours/year (EG&G, 1992).

Regulatory Considerations for Waste Management Workers. Regulatory requirements have been established to limit exposures of workers to radionuclides and hazardous chemicals. These requirements are generally considered to be conservative to ensure safe conditions for workers. Code of Federal Regulations, Title 10, Chapter 835 (abbreviated "10 CFR 835") and DOE Order 5480.11 specify that the maximum allowable worker exposure to radionuclides is 5 rem/year. However, DOE installations institute their own additional radioactive waste operations procedures and administrative exposure limits for workers. DOE facilities adhere to the principle that radiological exposures should be kept "as low as reasonably achievable" (the "ALARA" principle). Guidance documents such as the Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, Standard Operating Safety Guides, and Field Standard Operating Procedures provide information oriented toward reducing exposures at hazardous waste sites. One of the primary assumptions of the worker risk analysis is that waste management worker exposures do not routinely exceed occupational exposure limits. This assumption is based on historical occupational exposure data showing that workers involved in routine operations are generally exposed to levels less than these limits. According to the DOE Radiological Control Manual (DOE, 1994), the DOE Administrative Control Level per person is 2,000 mrem. However, the Manual also states that "an annual facility Administrative Control Level of 500 mrem or less should be challenging and achievable. An annual facility Administrative Control Level above 1,500 mrem is in most cases not sufficiently challenging to meet the goals of this Manual." Therefore, for the worker risk analysis, the radiation exposure guideline of 1,000 mrem/year (1 rem/year) is assumed to be the upper bound of worker exposure to radiation.

Estimated air concentrations are also compared to occupational exposure criteria such as TLVs for chemicals and EPA derived air concentrations for radionuclides to evaluate worker exposure conditions. The methodology used to estimate worker risks assumes the use of good work practices under normal conditions. If a TLV is not available for a particular chemical, estimated air concentrations of that chemical may be compared instead to 10% of the IDLH concentration, as established by the National Institute for Occupational Safety and Health (1992). The IDLH level is defined as the maximum air concentration to

which an individual without a respirator can be exposed for 30 min without suffering escape-impairing or irreversible health effects; 10% of that level is considered the boundary between negligible and reversible health effects for a 30-min exposure (ORNL, 1995b).

Estimating Doses From Indoor Air. For indoor scenarios in which individuals work inside treatment, storage, and disposal facilities, air concentrations are estimated using a room model (Jayjock, 1988). Contaminant releases are assumed to be distributed evenly throughout the entire volume of the room where treatment takes place. Intakes or doses from inhalation are estimated for each module, contaminant, and worker classification. For the worker risk evaluation, 10% of the stack emissions are assumed to escape from the module into the room (EPA, 1989b). Stack emission rates from treatment, storage, and disposal facilities are provided by ANL. Dose conversion factors used to calculate committed EDEs for inhalation of radionuclides are obtained from the EPA (EPA, 1988).

Estimating Doses From External Radiation. Doses received by treatment, storage, and disposal workers from exposure to radiation from sources external to the body (not inhaled or ingested) are calculated by taking into account the capacity of each module, worker types and numbers, exposure durations, and available shielding. With the aid of the MicroShield computer model (Grove Engineering, 1992), a "unit" EDE is calculated for workers within each module. MicroShield modeling is performed assuming that a unit concentration (1 Ci/m^3) of each radionuclide is present. Since treatment periods are assumed for a maximum of 10 years, radioactive decay and ingrowth of daughter products are considered for a five-year time period (average of the treatment period) in order to include external doses from photon-emitting daughter products.

D.2.8 Calculating Risks

This section describes how the unit doses and intakes estimated by modeling (as described in the previous section) are scaled up according to each site's source term and how the PEIS human health risk estimates are calculated for the various alternatives.

D.2.8.1 Scaling Unit Doses and Intakes According to Installation Source Term

For each site, a database is created of unit doses and intakes for all known contaminants. The database comprises numerous tables that contain waste-, site-, and exposure pathway-specific information. For radionuclides, the database contains tables of unit doses by site, receptor, contaminant, and pathway. For chemicals, the database contains tables of unit intakes by site, receptor, contaminant, and pathway.

Once unit doses and intakes have been estimated for the contaminants at a particular site for a particular alternative, they are scaled up based on the waste inventory at that site. To estimate exposures to the offsite and noninvolved populations, intruder, and farm family posed by a particular contaminant at the site, the inventory for that contaminant is first multiplied by the fraction of contaminant released during treatment, storage, and disposal activities. This product, the source term, is the estimated amount of contaminant released to the environment that could result in exposure via ingestion or inhalation. To estimate worker exposures, the unit exposure values are scaled by the inventory of contaminant present in each module for a particular site.

D.2.8.2 Calculating Risks From Unit Doses and Intakes

Calculating Risks for Noncarcinogens. The health risk value for each noncarcinogenic hazardous chemical is estimated by dividing the intake by the appropriate chemical-specific toxicity value (e.g., the EPA RfD) for all receptors but waste management workers. For workers, the estimated air concentration is divided by the ACGIH TLV. The resulting quotients (called the "hazard quotient" and "exposure ratio," respectively) express how closely the exposure to this toxicant, under the conditions in the exposure scenario, approaches the EPA or ACGIH exposure standard (this concept is explained in greater detail in Sections D.2.9, D.2.10, and D.2.11).

Calculating Risks for Carcinogens. Risks for carcinogens are estimated by multiplying the unit dose or intake by the appropriate cancer risk values from the EPA and the ICRP. For chemical carcinogens, EPA chemical-specific cancer potency factors are used (EPA, 1991b). The risk factors used for radionuclides are published in *ICRP 60* (ICRP, 1990). The radiological risk factors for the public (all receptors except waste management workers) and waste management workers are shown in Table D.2–3.

Table D.2–3. ICRP Radiological Risk Factors Used in the PEIS Human Health Risk Evaluation

Endpoint	Risk Factor for Public Receptors[a]	Risk Factor for Workers
Cancer incidence	0.0017/rem-lifetime	0.0014/rem-lifetime[b]
Cancer fatality	0.0005/rem-lifetime	0.0004/rem-lifetime[b]
Genetic effects	0.0001/rem-lifetime[c]	0.00006/rem-lifetime[c]

[a] Public receptors include offsite population and noninvolved workers.
[b] The nominal probability coefficient for fatal cancers is used to derive the cancer incidence nominal probability coefficient. The probability of fatal cancer, F (which for workers is 80% of F, as described in *ICRP 60*) is divided by the lethality fraction, k, for each organ. The total cancers per organ are then summed over all organs to result in total cancer incidence nominal probability coefficient of 0.0014.
[c] Includes weighting for severity of hereditary effects, but not for years of life lost should harm occur.

Source: ICRP (1990).

As stated above, these factors are multiplied by the EDE or committed EDE (for internal radiological exposures) sustained by a receptor or group of receptors to yield risk estimates associated with radiation exposure. The *ICRP 60* risk factors are consistent with the recommendations of the DOE Office of National Environmental Policy Act Oversight and are contained in the preamble to the U.S. Nuclear Regulatory Commission's Standards for Protection Against Radiation, 56 *Fed. Reg.* 23363.

In comparing the risks from radionuclide exposures with the risks from chemical carcinogen exposures, it is important to note that radionuclide and chemical carcinogen risks are determined by different methods. The dose conversion factors and risk factors used to estimate radionuclide-associated risks are based on observed potency in humans (typically studies of atomic bomb victims). The slope factors used to estimate chemical-carcinogen-associated risks are derived from animal studies and believed to be more conservative as a result of the uncertainty in extrapolating results for humans. These differences in risk estimation should be considered when comparing radionuclide and chemical carcinogen risks.

Risk Factors for Construction and Operational Hazards. Construction and operational risks are calculated based on current Bureau of Labor Statistics and National Safety Council statistics for the number of construction fatalities per 100,000 full-time workers; the rate of injuries, illnesses, or lost work days per 100 full-time workers over 200,000 work hours; and the risk of operational fatality, illness, or injury to

sanitary (sewerage and refuse) services workers (including both government and private industry employees).

Calculating Risks to the Public (All Receptors Except Waste Management Workers). The following example summarizes the steps involved in calculating risk for the offsite population:

- **Calculating Unit Dose**—Assuming that 1 Ci of plutonium–238 is released per year from one treatment module in LLW Treatment Facility No. 2 at Site X, a unit dose of 0.0001 rem/Ci/year is calculated, using the computer model GENII, for inhalation of plutonium–238 by the offsite population.

- **Calculating Exposure to Public Receptors**—The unit dose of 0.0001 person-rem/(Ci/year) is multiplied by the source term, which is the inventory of plutonium–238 (expressed in Ci) released per year. Assuming that the source term for plutonium–238 emissions from one treatment module in LLW Treatment Facility No. 2 at Site X is 20 Ci/year:

$$0.0001 \text{ person-rem/(Ci/year)} \times 20 \text{ Ci/year} = 0.002 \text{ person-rem} \qquad \text{(D.2-1)}$$

- **Calculating Annual Risk of Cancer Fatalities**—The annual risk for cancer fatalities resulting from the release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Site X is calculated by multiplying the dose calculated in equation (1) above by the risk factor for cancer fatalities for the offsite population (Table D.2–3) to obtain the annual risk for release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Site X:

$$0.002 \text{ person-rem} \times 0.0005/\text{person-rem} = 0.000001 \text{ (or one in one million)} \qquad \text{(D.2-2)}$$

- **Calculating Cumulative Risk for Entire Release Period**—To calculate the cumulative cancer fatality risk release of plutonium–238 from one treatment module in LLW Treatment Facility No. 2 at Site X for the entire 20-year release period, the annual risk calculated in equation (2) above is multiplied by 20:

$$0.000001/\text{year} \times 20 \text{ years} = 0.00002 \text{ (or 2 in 100,000) over 20 years} \qquad \text{(D.2-3)}$$

The risks for all of the contaminants in the site's source term are calculated as described in the four steps above, then summed to yield the total risk for each exposure pathway. The risks for each pathway

associated with a treatment module are summed to give a risk for each module. The risks for all modules are summed to give a risk for each waste type. The risks for treatment of each waste type at a site can then be summed to give the site's total risk. Population risk estimates represent the estimated number of occurrences of a health effect such as cancer incidence, cancer fatality, or genetic effects within the total population. A risk estimate for an individual (i.e., for the MEIs) is the estimated probability that the individual will develop a particular health effect.

Calculating Risks to Waste Management Workers. Risks to waste management workers from exposure to a unit amount of contaminant are estimated using unit doses similar to the those described above. Worker risks are calculated by the following steps:

- Waste management modules, treatment trains, worker types, and staffing estimates are characterized as described in Section D.2.7.2.
- Unit doses and intakes for each technology or module are then calculated.
- Worker exposures are estimated based on unit intakes and doses, site/module-specific contaminant inventories and waste throughputs, and module-specific person-hours required to perform the selected technologies or activities.
- The risks of injury and death from physical trauma (crushing, burning, electrocution, etc.) during construction and operation of waste management facilities are calculated based on worker person-hours and current Bureau of Labor Statistics and National Safety Council data, as described in Section D.2.8.1 and the ORNL worker risk methodology (ORNL, 1995b).

For example, assume that a rate of 0.00005 deaths per person-hour from physical trauma is expected for workers involved in heavy construction. If an estimated 20,000 person-hours are required to build a treatment facility, then:

$$20{,}000 \text{ person-hours} \times 0.00005 \text{ deaths/person-hour} = 1 \qquad \text{(D.2-4)}$$

Therefore, one death is estimated to occur during facility construction.

D.2.9 CALCULATING AND INTERPRETING THE HAZARD INDEX

The hazard index is an indicator of the total *additive*, noncancer toxicity from exposure to mixtures of hazardous chemicals (EPA, 1991a). It is calculated for the offsite and noninvolved worker MEIs at each site, by alternative, for both routine waste management operations and potential accidents. The highest offsite and noninvolved worker hazard indices for a particular alternative represent the estimated highest noncarcinogenic chemical exposure that an offsite individual and individual noninvolved worker, respectively, would receive at any site under that scenario.

The first step in calculating the hazard index is to estimate the receptor's predicted exposure to a hazardous chemical in the waste mixture, and divide the predicted exposure level by that chemical's maximum acceptable level (the level to which a person can be exposed 24 hours/day over a 70-year lifetime without developing adverse effects). These maximum acceptable levels are determined based on EPA RfDs and RfCs.

The resulting number from this calculation is the "hazard quotient." Hazard quotients are calculated for all of the hazardous components in the mixture and the results are summed to yield the hazard index.

Hazard index estimates should be interpreted according to EPA risk assessment guidelines (EPA, 1991a). According to this guidance, if the hazard index is less than or equal to 1.0, the exposure is unlikely to produce adverse toxic affects. However, the closer the hazard index is to 1.0, the more concern about the potential hazard of the chemical mixture increases. If the index exceeds 1.0, the concern is the same as if an individual chemical exposure had exceeded its acceptable level by the same proportion. While the hazard index does not provide a statistical probability that a particular mixture at a particular exposure level will cause a particular adverse effect (recall that below-threshold exposures for single components of a mixture may not contribute to adverse effects), it can serve as an indicator of the *relative potential for causing harm.* For a more detailed explanation of this concept, refer to supporting technical reports by ORNL (1995b,c).

If a contaminant has no RfD, it is excluded from the public risk analysis and the effect of excluding it is discussed in the results.

D.2.10 Calculating and Interpreting the Exposure Index

For routine waste management operations, the exposure index is calculated for the maximally exposed FTE ("worker equivalent") instead of the hazard index. Like the hazard index, the exposure index is an estimate of the greatest total noncancer toxicity from exposure to hazardous chemicals (EPA, 1991a). However, it is based on occupational exposure (which is episodic) rather than continuous, residential-type exposure.

The first step in determining the exposure index is to divide the concentration of each hazardous chemical in the workroom air by its TLV to yield an "exposure ratio" for each chemical. TLVs are typically time-weighted average exposure concentrations considered safe for a normal 8-hour (or 10-hour) work day and a 40-hour work week. The TLVs for an 8-hour work day were used for this analysis when available (ACGIH, 1992).

The exposure ratios for all of the chemicals in the workroom air are summed to determine the exposure index. Results greater than 1.0 indicate exposure at levels higher than recommended and an increased likelihood of adverse health effects. Similar to the hazard index, the exposure index in the results shows the highest chemical exposure to the maximally exposed FTE at any site under a particular alternative.

If no TLV or IDLH concentration has been determined for a particular contaminant, it is not included in the worker risk estimates. If an excluded contaminant comprises a significant percentage of the waste, the results discussion for that waste addresses the effect of excluding it.

D.2.11 Calculating and Interpreting the IDLH Index for Accidents

For *accidents* involving hazardous, noncarcinogenic wastes, the IDLH index (NIOSH, 1992), instead of the exposure index, is determined for FTEs. The IDLH index is similar in concept to the exposure index and is calculated similarly for the maximally exposed FTE at any site under a particular alternative. However, it is based on comparison to contaminant air concentrations that impair escape or are immediately dangerous to life and health if exposure lasts more than 30 min. An IDLH index greater than 1.0 indicates an increased likelihood of immediate danger to life and health (whereas an exposure index greater than 1.0 indicates exposure at a level higher than recommended for a safe work environment). The IDLH index is used for accidents based on the assumption that if exposure to a contaminant does not impair escape or

threaten health or life for at least 30 min, this exposure does not impair escape or threaten health or life in the few seconds or minutes postulated for the accident scenarios analyzed in this part of the PEIS.

D.2.12 Assessing the Risks From Potential Accidents

This section provides a brief overview of the methodology for calculating accident risks; additional details can be found in (ORNL, 1995b).

There are two general types of accidents likely to affect waste management operations: operational accidents involving waste management workers in the course of routine waste management activities; and external events, which are accidents caused by forces or events outside of waste management operations. Operational accidents include handling mishaps, explosions, uncontrolled reactions, fires, and leaks or spills. External events include those caused by humans (such as airplane crashes) and natural phenomena (such as earthquakes, extreme winds or tornadoes, and volcanoes). One or more of these types of accidents were postulated and evaluated for all WM Program waste types as part of the PEIS human health risk analysis. The rationale for the design and selection of the PEIS accident scenarios can be found in Appendix F. In general, accidents for which the attendant risks are potentially highest (such as an earthquake followed by fire and explosion) and accidents that are likely to occur during waste management operations (such as drum-handling accidents) have been selected to represent the spectrum of potential accidents.

In all accident scenarios, one shift of workers is assumed to be present in the facility when the accident occurs. The workers are assumed not to be using personal protective equipment because adequate engineering and administrative controls are assumed to be in place to protect them during routine operations. It is assumed that workers are not blocked or injured by falling or burning debris, and are not so overcome by heat or smoke that they cannot escape from the accident scene. The injuries or fatalities considered in the risk analysis result solely from the radiological and/or chemical exposure the workers receive in the accident.

It is assumed that when an accident occurs, the released contaminants mix uniformly into a specified volume of air. The size and shape of this volume vary according to waste type and accident scenario. The concentration of contaminants in this volume of air is the concentration to which workers are exposed. Exposure durations vary depending on the type of accident and whether it occurs indoors or outdoors. Any

contamination that escapes during the accident is assumed to disperse to the offsite and noninvolved worker populations via the atmosphere. Both populations are at risk from inhaling contaminated air. In addition, the offsite population may be directly exposed by contaminated soils, and by ingesting contaminated water, soil, meat, and agricultural products (ORNL, 1995a). The resulting health effects and their duration depend on the type of contaminant(s) released and the exposure pathway(s) and route(s) (ORNL, 1995a). Because the exposure pathways and routes may be different for the offsite and noninvolved worker populations than for workers, the contaminant of greatest concern to these nonworker populations may be different from the contaminant causing the most risk to workers.

The population distributions and meteorological monitoring data used in the accident analyses can be found in the technical report, "PEIS Installation Descriptions" (ORNL, 1995d). Any additional assumptions used in evaluating accident risks are noted in the text where appropriate.

D.2.12.1 Predicted Annual Frequency of Accidents

Each accident type in the PEIS risk evaluation is assigned an estimated annual frequency of occurrence as follows (see Appendix F):

- Anticipated (greater than 1 chance in 100 years)
- Unlikely (between 1 chance in 100 and 1 chance in 10,000 years)
- Very unlikely (between 1 chance in 10,000 and 1 chance in 1,000,000 years)
- Extremely unlikely (less than 1 in 1,000,000 years)

For example, incinerator ash explosions during the processing of LLW are considered to be anticipated, while a large aircraft impact with resulting fire and explosion is considered extremely unlikely.

The accident risk estimates presented in the results section reflect only the *consequence* of each accident as though it occurs; the estimated annual frequency is not factored into these results. However, when considering the results, readers should bear both of these parameters in mind. There may be cases in which an accident scenario has extremely serious projected consequences but the probability that it will occur is extremely remote. Conversely, an accident with relatively small consequences may be of substantial concern because it is predicted to occur relatively often.

D.2.13 CONTENTS OF THE RISK ANALYSIS TABLES

The risk analysis results tables in the subsequent sections of this appendix present a breakdown of the total human health risks associated with managing and disposing of that waste under its waste consolidation alternatives. For each of the waste types, the tables show:

- The estimated risk to each total offsite and noninvolved worker population, their respective MEIs, and waste management workers of developing cancer, dying of cancer, or suffering adverse genetic effects from exposure to chemicals and/or radionuclides, by alternative and site
- The risks to waste management workers of death or injury from physical trauma during waste management activities and the construction of waste management facilities, by alternative and site (it is assumed that no contaminants are released during these events so physical hazards can be assessed separately from chemical and radiological hazards)
- A hazard index calculation for the offsite and noninvolved worker MEIs, indicating the greatest likelihood of noncancer toxicity from continuous exposure to chemical contaminants, by alternative
- An exposure index calculation for the maximally exposed FTE (hypothetical worker or "worker equivalent"), indicating the greatest likelihood of noncancer toxicity effects from work-day (episodic) exposure to chemical contaminants, by alternative
- The risks to waste management workers, the maximally exposed generation of the hypothetical farm family, and all generations of the farm family from disposal of LLW and LLMW, by alternative and site
- The risks to the hypothetical intruder for intrusion at 100 years and 300 years, by alternative
- The risks to all populations and MEIs from potential accidents, by alternative

D.2.14 READING AND INTERPRETING THE RISK AND PROBABILITY NUMBERS

The numbers in the results tables are displayed in the standard "scientific" (exponential) notation used in risk assessment and are read as follows. Assume that a table contains the entry 5.0E–01 to represent the total estimated operations fatalities to waste management workers incinerating a particular waste under a Regionalized Alternative. The notation "E–01" indicates the power of 10 by which the leftmost, two-digit number (in this case, 5.0) is to be multiplied. Therefore, 5.0 is multiplied by 10^{-1} (0.1) to yield 0.5. This result means it is predicted that nationwide operations for that waste type under this Regionalized Alternative will result in an estimated 0.5 fatality during routine incineration operations over the total processing period for that waste (e.g., 10 or 20 years). Note that the estimate in this example is a fraction

of 1, that is, a number less than 1. This means that over the period studied (under the assumptions used in the risk analysis), no waste management workers are estimated to die as a result of routine incinerator operations. (However, note that there is some degree of error in any risk estimate due to uncertainties in the assumptions, data, models, etc., used to perform the analysis; see Sections D.2.15 and D.4).

Probability is expressed as a number between zero and one. If there is no chance that a particular event will occur, it is assigned a probability of zero; if that event is certain to occur, its probability is one. The probability that the offsite and noninvolved worker MEIs will develop or die of cancer, or manifest noncancer toxicity, etc., is expressed in the same notation as risk. Assume that a table contains the entry 3.0E-06 to represent the probability that the noninvolved worker MEI for a particular waste type scenario will develop cancer from exposure to a radioactive waste. The notation 3.0E-06 indicates that 3.0 is multiplied by 10^{-6} (0.000001). Therefore, this probability is 0.000003, which means that there are 3 chances in 1,000,000 that, over the total waste processing period, the noninvolved worker MEI will develop cancer from exposure to that radioactive waste. (Again, note that this estimate will be affected by any uncertainties associated with the risk calculations.)

As discussed in preceding sections, the maximum exposure to workers allowed under 10 CFR 835 and DOE Order 5480.11 is 5 rem/year. In contrast, DOE Order 5400.5 states that the maximum annual allowable radiation dose to the members of the public from DOE-operated nuclear facilities is 100 mrem/year. For perspective, it is estimated that the average individual in the United States receives a dose of about 300 mrem (0.3 rem)/year from all sources combined, including medical sources of radiation (such as x-rays) and natural background radiation (such as radon gas). A modern chest x-ray results in a dose of approximately 8 mrem, while a diagnostic hip x-ray results in a dose of approximately 83 mrem. A person must receive an acute (short-term) dose of approximately 600,000 mrem before there is a high probability of near-term death (NAS/NRC, 1990). Another relevant benchmark is the disposal standard for spent nuclear fuel, HLW, and TRUW (40 CFR 191), which states that disposal of these materials in compliance with the containment requirements should not result in MEI doses greater than 15 mrem/yr.

Note that the estimated risks of injury to waste management workers take into account all on-the-job injuries from the most minor to the most severe. Similarly, the risks to all receptors of adverse effects from noncarcinogenic, hazardous chemicals (expressed as the hazard and exposure indices) consider all adverse manifestations with no indication of their severity.

Finally, there are two ways to examine and compare the risks between alternatives in this risk analysis: at the *program level* and at the *site level*. This is illustrated in the following example.

Consider a Decentralized Alternative (for example, Hypothetical Alternative 1) that affects the populations at 14 sites and a Centralized Alternative (Hypothetical Alternative 2) that affects the population at only 1 site. If the total risks across all sites in Hypothetical Alternative 1 are *numerically* higher than the total risks for the one site in Hypothetical Alternative 2, Hypothetical Alternative 1 is the highest-risk alternative at the *program level*. However, the reader may find it useful in some instances to look at these risks at the *site level* as well.

Suppose the overall programwide risk of cancer incidence from radionuclide exposure in Hypothetical Alternative 1 is 8.0E–01, and this total risk is distributed across 23 million people, the sum of the offsite populations at all 14 sites involved in that alternative. If this programwide risk, 8.0E–01, is divided by the total affected population, 23 million, the resulting number is:

$$\text{8.0E–01 (total risk for alternative)} \div \text{23,000,000 people affected overall} = \text{3.5E–08} \quad \text{(D.2-5)}$$

This result, 3.5E–08, might be considered the "average" risk to an individual member of the programwide offsite population. (Note that this number is *not* the risk to the MEI, and will *in all cases* be less than the risk to the MEI. This is because, on average, individual members of the population receive less exposure, by definition, than the MEI, the maximally exposed member of the population.)

D.2.15 Overview of Uncertainties in the PEIS Risk Analysis Process

The results of any human health risk assessment are conditional estimates based on multiple assumptions about exposure, toxicity, release of contaminants into the environment, human behavior patterns, and other variables. Therefore, the uncertainties accompanying the analysis should be evaluated to place these risk estimates in proper perspective. Uncertainties can be classified into three broad categories:

- Model uncertainty
- Scenario uncertainty
- Parameter uncertainty

Model uncertainty can result from the general limitations of mathematical models. Modeling involves trying to simulate a process that is inherently complex using a fixed and relatively small number of variables. Model uncertainty is usually estimated in the verification and validation phase of model development. Model uncertainty can also result from the inappropriate application of a model to a particular scenario (for instance, in situations for which no model has been specifically designed, and existing models must be adapted for use).

Scenario uncertainty may result from a generalized or incorrect conceptualization of a contaminant release or an exposure scenario. For example, there may be errors in the generalized assumptions concerning the amount of contaminants released, the spatial distribution of potential receptors, and the intake parameters considered for the receptors.

Parameter uncertainty may result from sampling errors, natural variability of the parameter, or the use of generic data (data that are not site-specific). The fate and transport models used to estimate risks for the PEIS require large amounts of data, including meteorological measurements, hydrogeologic settings, and release parameters. Actual data are used where possible, but generic data are often substituted where site-specific data are unavailable.

Keep in mind that the goal of the PEIS risk analyses is to evaluate the *relative* differences in risks among the various waste management alternatives if implemented nationwide. The assumptions made in performing this program-level evaluation were intended to yield reasonably conservative risk estimates (i.e., estimates that tend to overestimate rather than underestimate risk) using the best available data and state-of-the-art models. Given the programmatic nature of the PEIS and the use of the unit approach to risk assessment (ORNL, 1995c), many of the uncertainties associated with the PEIS risk estimates are "systematic." That is, many modeling and scenario assumptions were applied consistently—that is, "systematically"—throughout the analysis (such as facility emission rates for particular types of waste treatment or storage, inhalation rates, etc.). Therefore, the *relative* differences in risk estimates among waste management alternatives should not be affected by errors associated with these systematically applied assumptions. For example, if consumption of contaminated agricultural food products by the offsite population was overestimated for one alternative, it was similarly overestimated for all other alternatives.

Other uncertainties in risk estimates may be specific to assumptions about a particular scenario or site (such as wind conditions, crop yields, etc.). Section D.4 presents an evaluation of some of these parameter

uncertainties associated with the PEIS health risk estimates. In addition, readers may also wish to refer to the modeling literature cited in the reference list.

D.3 Risk Analysis by Waste Stream

This section contains a summary of the risk analysis for both routine waste management operations and potential accidents associated with each of the DOE WM Program waste streams. The information for each waste stream includes a brief definition of the waste, an overview of the alternatives analyzed, the special assumptions and considerations used in the analysis, tables showing the results of the analysis, and results summaries.

D.3.1 High-Level Waste

High-level waste (HLW) is the highly radioactive material resulting from the reprocessing of spent nuclear fuel. When spent nuclear fuel is reprocessed, reactor fuel elements are divided and dissolved to separate plutonium and uranium from their fission products; the plutonium and uranium can then be reused. The byproduct, HLW, includes liquid waste produced directly in reprocessing as well as any solid waste derived from the liquid, and contains a combination of TRUW and fission products in concentrations requiring careful handling and permanent isolation (DOE, 1988). Because a variety of solvents, acids, and alkaline agents are used in spent nuclear fuel reprocessing as well as in treatment, HLW may also contain hazardous waste components (nonradioactive but hazardous substances subject to Resource Conservation and Recovery Act regulation). However, once HLW has been vitrified (vitrification involves mixing the waste with glass-forming frit; heating the mixture to fuse it into a glass, ceramic, or other noncrystalline solid; and storing the immobilized waste in sealed, decontaminated metal canisters), these are no longer present or are immobilized in the glass matrix and are no longer emitted. DOE has determined that spent nuclear fuel reprocessing will be phased out as soon as possible; therefore, liquid HLW will no longer be generated in the future.

Four sites manage DOE-owned HLW (note that the abbreviations given here are used in the tables in this appendix):

- Hanford Site (Hanford), Richland, Washington

- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

Because DOE has already selected vitrification as the method for immobilizing HLW, evaluations were performed only for the worker risks associated with interim storage of the resulting HLW canisters pending final disposal in a national geologic repository. Public risks were not evaluated for interim storage because the offsite population would be at negligible risk of exposure. However, public risks were calculated for potential accidents; the results are presented in Sections D.3.1.5 through D.3.1.7. Transportation risks are presented in Appendix E.

Chapters 3 and 9 of the PEIS and the HLW technical report (ANL, 1996a) provide more detailed information on this waste including HLW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, and the process for developing the PEIS HLW alternatives.

D.3.1.1 Summary of HLW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing them are discussed rigorously in the main body of the PEIS. Five HLW alternatives (the No Action, Decentralized, Regionalized 1, Regionalized 2, and Centralized Alternatives) were analyzed. For each alternative, two cases—designated Storage Cases 1 and 2—were analyzed. In Storage Case 1, it was assumed that a geologic repository would be available in 2015 and would accept HLW canisters at a rate of 800/year. In Storage Case 2, it was assumed that there would be a delay in the availability of a geologic repository past 2015, but that when the repository began accepting HLW, it would accept canisters at a rate of 800/year. For each alternative except the Centralized Alternative, the number of canisters produced and stored at each site is identical between Storage Cases 1 and 2. In Storage Case 1 of the Centralized Alternative, Hanford stores only the portion of canisters produced by SRS until 2015; and in Storage Case 2 of the Centralized Alternative, Hanford stores all of the SRS canisters.

- In the No Action Alternative, HLW canisters are stored in existing and approved interim storage facilities at Hanford, SRS, and WVDP. No interim storage facility exists or has been approved for INEL; therefore, no risks are calculated for INEL under the No Action Alternative.

- In the Decentralized Alternative, each of the four sites continues to store its own inventory of immobilized HLW awaiting ultimate disposal in a national geologic repository.
- In the Regionalized Alternative 1, 340 vitrified canisters of HLW from WVDP are shipped to SRS to be stored there until final disposition. Hanford and INEL store their own HLW.
- In the Regionalized Alternative 2, 340 canisters of HLW from WVDP are shipped to Hanford for interim storage. SRS and INEL store their own HLW.
- In Storage Case 1 of the Centralized Alternative, 2,373 canisters from SRS and 340 from WVDP are transported to Hanford for interim storage until a geologic repository is available. The remaining canisters produced at SRS (2,199) are stored onsite until a geologic repository is in operation. In Storage Case 2, Hanford stores all SRS, INEL, and WVDP canisters (a total of 21,612) and would require additional storage capacity.

Construction hazards were analyzed for the sites where additional storage facilities would be needed until the opening of a national geologic repository in the year 2015 or later.

Table D.3.1–1 depicts the five HLW alternatives and shows which sites ship their wastes to regional or central consolidation sites for interim storage. The numbers in parentheses are the numbers of canisters stored at the site. For each alternative, Storage Cases 1 and 2 are identical to one another except in the Centralized Alternative, in which Hanford would store all of the SRS, WVDP, and INEL canisters (making a total of 21,612 HLW canisters at Hanford).

D.3.1.2 Special Assumptions and Considerations Used in the HLW Risk Analysis

Once HLW has been vitrified, sealed in stainless steel canisters, decontaminated, and moved into dedicated storage, there is expected to be very little risk of exposing the public to these materials under routine (nonaccident) conditions; therefore, only routine operational worker risks associated with interim storage of treated HLW were evaluated. These include risks associated with exposure to radiation and with operational or construction hazards. Risk estimates were based on expected worker person-hours associated with loading and storage activities. Potential exposures and health risks to the public and workers from accidental releases during HLW storage are considered in Sections D.3.1.5, D.3.1.6, and D.3.1.7.

Table D.3.1-1. PEIS Waste Consolidation Alternatives for HLW

Alternative		Hanford	INEL	SRS	WVDP
No Action (both storage cases)	Ship	--	--	--	--
	Store	Hanford (750)	--	SRS[a] (4,572)	WVDP (340)
Decentralized (both storage cases)	Ship	--	--	--	--
	Store	Hanford[a] (15,000)	INEL[a] (1,700)	SRS[a] (4,572)	WVDP (340)
Regionalized 1 (both storage cases)	Ship	--	--	--	Store temporarily for 6 years then ship 340 to SRS
	Store	Hanford[a] (15,000)	INEL[a] (1,700)	SRS[a] (4,912)	
Regionalized 2 (both storage cases)	Ship	--	--	--	Store temporarily for 16 years then ship 340 to Hanford
	Store	Hanford[a] (15,340)	INEL[a] (1,700)	SRS[a] (4,572)	
Centralized— Storage Case 1	Ship	--	--	Ship 2,373 to Hanford	Ship 340 to Hanford
	Store	Hanford[a] (17,713)	INEL[a] (1,700)	SRS (2,199)	--
Centralized— Storage Case 2	Ship	--	Ship 1,700 to Hanford	Ship 4,572 to Hanford	Ship 340 to Hanford
	Store	Hanford[a] (21,612)	--	--	--

Note: Numbers within parentheses are the numbers of canisters stored at the site.
[a] Construction of a new storage facility is required.

Interim storage is defined as long-term storage prior to disposal in a geologic repository. Temporary storage is defined as more short-term storage prior to shipment to another site for interim storage pending disposal in a geologic repository. For the purposes of this analysis, all shipments of HLW are assumed to be by truck.

It was assumed that the canisters are thoroughly decontaminated before they are transported to interim storage; this would remove any radioactive residue from the outside of a canister that could be inhaled, ingested, or transferred to the skin. Therefore, WM workers would be subject only to radiation that penetrates the HLW canister wall (this is termed "external" or "direct" radiation) and to the physical hazards associated with construction and routine facility operations. It was also assumed that HLW treatment would remove or immobilize any hazardous, nonradioactive components; therefore, there would be little or no risk of chemical carcinogenesis or toxic effects.

D.3.1.3 Results Tables for the HLW Human Health Risk Analysis

This section contains the results tables for the HLW human health risk analysis. A discussion of the results is presented in Section D.3.1.4. The fatality and cancer incidence numbers in the tables are displayed in

the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.1-2 presents an overview, by alternative (for Storage Case 1 only), of the *total*, programwide risks of cancer fatalities, cancer incidence, and construction and operational fatalities to waste management workers. This table provides the estimated *total number* of workers involved in storage and handling activities who will develop or die of cancers caused by exposure to HLW over the next 50 years if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities associated with storage and handling of HLW.
- Tables D.3.1-3 through D.3.1-7 show the programwide worker risks by health effect and Storage Case 1 alternative.
- Tables D.3.1-8 through D.3.1-12 present the worker population risks for each site, by Storage Case 1 alternative.
- Tables D.3.1-13 and D.3.1-14 present the incremental annual risk for each Storage Case 2 alternative (where the repository opening is delayed past 2015). These risk numbers show the additional risk per year from storage past 2015.
- Table D.3.1-15 presents the additional risks at Hanford for the Storage Case 2 Centralized Alternative. This alternative requires Hanford to accept all canisters of HLW produced at WVDP, INEL, and SRS which will result in more loading and unloading risks and additional construction risks.

Table D.3.1-2. Summary of Programwide Risks Associated With Routine Management of HLW: Risks to Worker Population Under Storage Case 1, by Alternative

Storage Case 1 Alternative	Total Fatalities[a]	CF	CI	C&OF
No Action	3.0	2.2	7.5E+01	8.1E-01
Decentralized	4.7	3.2	1.1E+01	1.5
Regionalized 1	4.8	3.3	1.1E+01	1.5
Regionalized 2	4.8	3.3	1.2E+01	1.5
Centralized	5.0	3.4	1.2E+01	1.6

Notes: CF = cancer fatality associated with exposure to radionuclides; CI = cancer incidence; C&OF = construction and operational fatalities.
[a] Sum of fatalities from construction, operation, and cancer associated with exposure to radionuclides.

Table D.3.1-3. Programwide Risks Associated With Managing HLW Under Storage Case 1 of the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM workers	Dose (FTE-rem)	5.4E+03	
	Cancer fatalities	2.2	
	Cancer incidence	7.5	
	Genetic effects	3.2E-01	
	Construction fatalities		7.9E-03
	Construction injuries		3.5
	Operation fatalities		8.1E-01
	Operation injuries		6.9E+02

Table D.3.1-4. Programwide Risks Associated With Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM workers	Dose (FTE-rem)	8.1E+03	
	Cancer fatalities	3.2	
	Cancer incidence	1.1E+01	
	Genetic effects	4.8E-01	
	Construction fatalities		1.4E-01
	Construction injuries		6.2E+01
	Operation fatalities		1.3
	Operation injuries		1.1E+03

Table D.3.1-5. Programwide Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM workers	Dose (FTE-rem)	8.1E+03	
	Cancer fatalities	3.3	
	Cancer incidence	1.1E+01	
	Genetic effects	4.9E-01	
	Construction fatalities		1.4E-01
	Construction injuries		6.3E+01
	Operation fatalities		1.3
	Operation injuries		1.1E+03

Table D.3.1-6. Programwide Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM workers	Dose (FTE-rem)	8.2E+03	
	Cancer fatalities	3.3	
	Cancer incidence	1.2E+01	
	Genetic effects	4.9E-01	
	Construction fatalities		1.5E-01
	Construction injuries		6.4E+01
	Operation fatalities		1.4
	Operation injuries		1.2E+03

Table D.3.1-7. Programwide Risks Associated With Managing HLW Under Storage Case 1 of the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
WM workers	Dose (FTE-rem)	8.4E+03	
	Cancer fatalities	3.4	
	Cancer incidence	1.2E+01	
	Genetic effects	5.1E-01	
	Construction fatalities		1.7E-01
	Construction injuries		7.3E+01
	Operation fatalities		1.4
	Operation injuries		1.2E+03

Table D.3.1-8. Risks Associated With Managing HLW Under Storage Case 1 of the No Action Alternative, by Site

Site	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	1.5	3.8
INEL	0.0	0.0
SRS	1.3	3.4
WVDP	1.2E-01	2.8E-01
Total	3.0	7.5

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-9. Risks Associated With Managing HLW Under Storage Case 1 of the Decentralized Alternative, by Site

Site	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	2.5	6.1
INEL	8.0E-01	1.6
SRS	1.3	3.3
WVDP	1.2E-01	2.7E-01
Total	4.7	1.1E+01

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1-10. Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 1, by Site

Site	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	2.5	6.1
INEL	8.0E-01	1.6
SRS	1.4	3.5
WVDP	7.8E-02	1.7E-01
Total	4.8	1.1E+01

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1–11. Risks Associated With Managing HLW Under Storage Case 1 of Regionalized Alternative 2, by Site

Site	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	2.6	6.4
INEL	8.1E–01	1.6
SRS	1.3	3.3
WVDP	1.0E–01	2.3E–01
Total	4.8	1.2E+01

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1–12. Risks Associated With Managing HLW Under Storage Case 1 of the Centralized Alternative, by Site

Site	Worker Risks	
	Total Fatalities[a]	Cancer Incidence
Hanford	3.0	7.2
INEL	8.3E–01	1.6
SRS	1.1	2.7
WVDP	1.0E–01	2.3E–01
Total	5.0	1.2E+01

[a] Includes fatalities associated with both radiation exposures and physical hazards.

Table D.3.1–13. Storage Case 2: Incremental Annual Exposure Risks Associated With Storage Beyond 2015, in Risk per Year

Storage Case 2 Alternative	Hanford			INEL			SRS			WVDP		
	CF	CI	GE	CF	CI	GE	CF	CI	GE	CF	CI	GE
No Action	2.4E–03	8.4E–03	3.6E–04	0.0	0.0	0.0	7.2E–03	2.5E–02	1.1E–03	1.6E–03	5.6E–03	2.4E–04
Decentralized	3.6E–02	1.3E–01	5.4E–03	3.2E–03	1.1E–02	4.8E–04	7.2E–03	2.5E–02	1.1E–03	1.6E–03	5.6E–03	2.4E–04
Regionalized 1	3.6E–02	1.3E–01	5.4E–03	3.2E–03	1.1E–02	4.8E–04	7.2E–03	2.5E–02	1.1E–03	0.0	0.0	0.0
Regionalized 2	3.6E–02	1.3E–01	5.4E–03	3.2E–03	1.1E–02	4.8E–04	7.2E–03	2.5E–02	1.1E–03	0.0	0.0	0.0
Centralized	5.0E–02	1.8E–01	7.6E–03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Notes: CF = cancer fatalities; CI = cancer incidence; GE = genetic effects.

Table D.3.1-14. Storage Case 2: Incremental Annual Operational Risks Associated With Storage Beyond 2015, in Risk per Year

Storage Case 2 Alternative	Hanford		INEL		SRS		WVDP	
	OF	OI	OF	OI	OF	OI	OF	OI
No Action	1.1E-03	9.2E-01	0.0	0.0	3.2E-03	2.8	7.2E-04	6.1E-01
Decentralized	1.6E-02	1.4E+01	1.4E-03	1.2	3.2E-03	2.8	7.2E-04	6.1E-01
Regionalized 1	1.6E-02	1.4E+01	1.4E-03	1.2	3.2E-03	2.8	0.0	0.0
Regionalized 2	1.6E-02	1.4E+01	1.4E-03	1.2	3.2E-03	2.8	0.0	0.0
Centralized	2.3E-02	1.9E+01	0.0	0.0	0.0	0.0	0.0	0.0

Notes: OF = operational fatalities; OI = operational injuries and illnesses.

Table D.3.1-15. Storage Case 2: Additional Loading, Unloading, and Construction Risks at Hanford

Storage Case 2 Alternative	Hanford						
	CF	CI	GE	OF	OI	CnF	CnI
Centralized	4.2E-01	1.5	6.3E-02	6.3E-02	5.3E+01	6.7E-02	2.9E+01

Notes: CF =cancer fatalities; CI = cancer incidence; GE = genetic effects; OF = operational fatalities; OI = operational injuries and illnesses; CnF = construction fatalities; CnI = construction injuries and illnesses.

D.3.1.4 Results of the HLW Human Health Risk Analysis for Routine Operations

In general, there are only slight differences in estimated worker cancer and physical hazard risks among the Storage Case 1 alternatives (in which the repository is assumed to be available in 2015; see Table D.3.1-2 and Tables D.3.1-3 through D.3.1-12). Programwide fatalities from cancer and physical hazards range from 2.3 to 5.8. The risks for each health endpoint differ by about a factor of two. The factors influencing the risks among the alternatives are: (1) the duration of interim storage; (2) the construction of new interim storage facilities at SRS, Hanford, and INEL; and (3) the volumes of HLW at SRS and Hanford. In the Storage Case 2 alternatives, for every year that operation of the repository is delayed past 2015, there are additional storage risks at certain sites depending on the alternative (see Tables D.3.1-13 and D.3.1-14). Table D.3.1-15 shows the additional risks at Hanford as a result of the increased number of canisters being shipped there for storage in the Storage Case 2 Centralized Alternative.

The lowest estimated cancer fatality risks are for the No Action Alternative in Storage Case 1. This is because there are fewer canisters at Hanford and the risks are zero at INEL. The risks for the Storage Case 1 consolidation alternatives (Decentralized, Regionalized, and Centralized) are higher by a factor of about 1.5. This increased risk is due to the relatively long time that SRS, Hanford, and INEL store their canisters—40 to 45 years at all three sites. These long storage periods are based on the assumption that the national geologic repository accepts 800 canisters/year; therefore, average canister shipping rates to the repository are about 400 canisters/year at Hanford and 200 canisters/year at the other sites. Note that in each of these consolidation alternatives, the canisters are moved from one site to another but the total number of canisters at all sites, hence, the total associated risk, stays approximately the same.

The risk of fatalities from physical hazards follows the same trend as the risk of cancer fatalities; Storage Case 1 risks for the Decentralized, Regionalized, and Centralized Alternatives (1.5 to 1.6) are approximately 2 times higher than the risks for Storage Case 1 of the No Action Alternative (8.1E–01). These higher risks are due to the extended loading and storage periods at Hanford and INEL; this means that more person-hours are devoted to storage activities in these alternatives than in the No Action Alternative. Because more HLW is present at SRS and Hanford, the highest estimated risks of total fatalities are associated with these two sites (see Tables D.3.1–8 through D.3.1–12).

D.3.1.5 Special Assumptions and Considerations Used in the HLW Accident Analysis

This section presents an overview of the types of potential accidents analyzed for the interim storage of immobilized HLW. For this analysis, ANL estimated source terms for the HLW facilities at Hanford and INEL for accidents involving a canister breach due to dropping, collision, or both. These accident source terms are site-specific but do not differ by alternative (i.e., a glass canister breach at a particular site is considered to have the same consequences regardless of the alternative under which the accident occurs). The probability or frequency of HLW accidents is not addressed. Instead, consequences are presented as if each accident occurs once over the course of HLW interim storage. However, this should *not* be construed as indicating the actual probability or frequency of the postulated storage accidents.

Two accident scenarios were evaluated to determine the risks from radiological exposure to the offsite population and MEI, the noninvolved worker population and MEI, and waste management workers. In both, it was assumed that one canister of vitrified HLW is breached inside the storage facility and produces

a cloud of pulverized, radioactive material. One shift of four waste management workers is assumed to be inside the facility when the accident occurs.

When the canister is breached, the contaminants are assumed to disperse in a hemispherical mixing volume with a radius of 5 m. The four waste management workers are 1 m away from the canister when it is breached and walk away at 1 m/s; therefore, the workers are exposed for 4 sec. It is assumed that the workers do not hold their breath while walking away. While immersed in the resulting cloud of contaminated air, the workers are subject to external radiation and to internal radiation exposure by inhalation.

In the first accident, the storage facility's high-efficiency particulate air (HEPA) filtration system is assumed to be fully functional when the canister is breached and only a small amount of the cloud of contaminated air escapes from the building. This material is atmospherically dispersed and presents a risk of internal and external exposure to the offsite and noninvolved worker populations and their respective MEIs.

In the second accident, the storage facility's HEPA filtration system is assumed to be completely disabled when the canister is breached. The entire cloud of contaminated air escapes from the building, is atmospherically dispersed, and presents a risk of internal and external exposure to the offsite and noninvolved worker populations and their respective MEIs.

For the worker exposure assessment, it was assumed that workers are always exposed to unfiltered releases, thus, the same unfiltered source term was used for both accident scenarios. As a result, worker risks are the same for both accident types at a particular site. The methodology and models for estimating worker risks are different from those used to estimate the risks that noninvolved worker and offsite receptors might receive from atmospheric releases (ORNL, 1995b). Because of this, air concentrations are different for workers than for nonworkers; controlling contaminants and exposure routes may also differ.

D.3.1.6 Results Tables for the Risk Analysis of Potential HLW Accidents

Table D.3.1–16 presents a programwide summary of the risks of cancer incidence and cancer fatality to all receptors, by accident type and site. Table D.3.1–17 provides the sizes of the offsite, noninvolved worker, and worker populations for each site. Table D.3.1–18 lists the contaminant contributing the most risk to the total offsite population and the dose contributed by that contaminant.

Table D.3.1-16. Summary of Risks From Potential HLW Accidents, by Accident Type and Site

Accident	Site	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI		Workers[a]	
		CF	CI	CF	CI	CF	CI	CF	CI	CF	CI
Filtered canister breach	Hanford	6.7E-06	2.3E-05	1.6E-10	5.3E-10	1.5E-07	5.2E-07	1.5E-09	5.1E-09	7.1E-03	2.5E-02
	INEL	1.5E-07	5.2E-07	1.8E-11	6.0E-11	5.6E-09	1.9E-08	3.3E-12	1.1E-11	4.8E-04	1.7E-03
Unfiltered canister breach	Hanford	3.3	1.1E-01	7.8E-05	2.6E-04	7.6E-02	2.6E-01	7.5E-04	2.6E-03	7.1E-03	2.5E-02
	INEL	7.7E-02	2.6E-01	8.9E-06	3.0E-05	2.8E-03	9.5E-03	1.7E-06	5.7E-06	4.8E-04	1.7E-03

Notes: MEI = maximally exposed individual; CF = risk of cancer fatality associated with radiological exposure; CI = risk of cancer incidence associated with radiological exposure.
[a] Worker exposures for a particular site are the same in both accidents.

Table D.3.1-17. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks From Potential HLW Storage Accidents, by Site

Site	Offsite Population	Noninvolved Worker Population	Worker Population
Hanford	377,645	8,674	4
INEL	153,061	8,451	4

Table D.3.1-18. HLW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population, by Accident Type and Site

Accident Type	Radionuclide and Dose, by Site	
	Hanford	INEL
Filtered canister breach	Strontium-90 7.1E-03 person-rem	Cesium-137 1.9E-04 person-rem
Unfiltered canister breach	Strontium-90 3.6E+03 person-rem	Cesium-137 9.4E+01 person-rem

Note: All exposures received via internal exposure (inhalation and ingestion).

D.3.1.7 Summary of the HLW Accident Analysis Results

As expected, the risks to all offsite and noninvolved worker receptors from the accident in which HEPA filtration is lost are markedly higher than the risks from the accident in which filtration is retained. As shown in Table D.3.1–16, estimated cancer incidence and fatalities for both populations and MEIs are 5 to 6 orders of magnitude greater for the unfiltered canister breach than for the filtered accident.

In the filtered canister breach, cancer incidence and fatality risks to all offsite and noninvolved worker MEI receptors are 1 to 5 orders of magnitude below 1.0E–06. In the unfiltered canister breach, cancer incidence and fatality risks exceed 1.0E–04 for the noninvolved worker MEI at Hanford, and are in the E–06 to E–05 range for the offsite and noninvolved worker MEIs at INEL.

In both accident scenarios, strontium–90 contributes most of the offsite population risk at Hanford and cesium-137 is the major contributor at INEL (see Table D.3.1–18). In both circumstances, the predominant exposure route is inhalation.

Worker exposure is the same in both accident scenarios (see Table D.3.1–16). Worker risks do not differ appreciably between the sites, and are highest at Hanford by less than 0.5 order of magnitude. The controlling radionuclides for worker exposure are strontium-90 at INEL and americium-241 at Hanford; inhalation is the principal exposure route.

D.3.2 Low-Level Waste

This section contains the human health risk analysis results for low-level waste (LLW). LLW includes all radionuclide-containing wastes not classified as high-level waste, transuranic waste with an activity greater than 100 nanocuries (billionths of a curie) per gram, spent nuclear fuel, or byproduct material as defined in Section 11e(2) of the Atomic Energy Act of 1954 (such as tailings containing uranium or thorium). Waste designated as LLW contains source, special nuclear, or byproduct material that is acceptable for disposal in a land disposal facility and does not contain hazardous components regulated under the Resource Conservation and Recovery Act (RCRA). LLW that contains hazardous components is classified as low-level mixed waste, which is addressed in Section D.3.5.

DOE generates LLW primarily in research and development, defense activities, uranium enrichment operations, and the naval nuclear propulsion program. About 30 sites within the DOE complex generate LLW, including those listed below:

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Argonne National Laboratory-West (ANL-W), Idaho Falls, Idaho
- Brookhaven National Laboratory (BNL), Brookhaven, New York
- Fernald Environmental Management Project (FEMP), Fernald, Ohio
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Kansas City Plant (KCP), Kansas City, Missouri
- Knolls Atomic Power Laboratory-Kesselring (KAPL-K), Schenectady, New York
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Naval Reactors Facility (NRF), Idaho Falls, Idaho
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Institute for Science and Education (ORISE), Oak Ridge, Tennessee
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee (comprises the Oak Ridge K-25 Site [K-25], the Oak Ridge National Laboratory [ORNL], and the Oak Ridge Y-12 Plant [Y-12])
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Pantex Plant (Pantex), Amarillo, Texas
- Pinellas Plant (Pinellas), Largo, Florida
- Portsmouth Gaseous Diffusion Plant (PORTS), Piketon, Ohio
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories–New Mexico (SNL-NM), Albuquerque, New Mexico
- Sandia National Laboratory–California (SNL-CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

This list includes the 16 major sites considered for LLW management described in Section 1.6.1 and Chapter 7 of Volume I and presented in Table D.3.2–1.

Table D.3.2–1. PEIS Alternatives for LLW

Alternative	Treat	Dispose	ANL-E	BNL	FEMP	Hanford	INEL	LANL	LLNL	NTS	ORR	PGDP	Pantex	PORTS	RFETS	SNL-NM	SRS	WVDP
No Action	10[a]	6				TD	TD	D	T	D	TD	T			T		TD	
Dec.		15	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Reg. 1		11			D	D	D	D	D	D	D	D	D	D	D		D	
Reg. 2	11	11			TD	TD	TD	TD	TD	D	TD	TD	TD	TD	TD		TD	
Reg. 3		6				D	D	D		D	D						D	
Reg. 4	7	6				TD	TD	TD		D	TD			T	T		TD	
Reg. 5	4	6				TD	TD	D		D	TD						TD	
Reg. 6		2				D											D	
Reg. 7		2								D							D	
Cen. 1		1				D												
Cen. 2		1								D								
Cen. 3	7	1				TD	T	T			T			T	T		T	
Cen. 4	7	1				T	T	T		D	T			T	T		T	
Cen. 5	1	1				TD												

Notes: T = treatment site. In this context, treatment entails volume reduction using thermal organic destruction, size reduction (shredding, etc.), and compaction followed by solidification. All sites perform minimum treatment in all alternatives; this consists of solidifying liquids and powdered material, packaging, and shipment. D = disposal site. Each of the 6-site disposal alternatives uses the same sites, and each of the 12-site disposal alternatives uses the same 12 sites. Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.

[a] Ten sites use existing facilities for volume reduction. Three sites not listed as major sites above (LBL, RMI, and Mound) include volume reduction facilities.

Note that treatment risks were estimated separately in this section of the WM PEIS for the three sites comprising ORR (e.g., ORNL, Y-12, and K-25) based on the assumption that Y-12 and K-25 perform only the packaging and certification/shipment modules, while ORNL undertakes these plus additional modules such as aqueous treatment, solidification, tumulus disposal, and incineration (where applicable). Disposal risks were calculated for the combined three sites based on the assumption that disposal of LLW from all three sites takes place at one central ORR facility.

Treatment sites were also estimated separately later in this section in Tables D.3.2–20 through D.3.2–32 for several other sites in addition to the 16 major LLW management sites. These sites include KAPL-K, LBL, KCP, Mound, and Pinellas. In Chapter 7 of Volume I, treatment risks for ORNL, ORISE, K-25, and Y-12 have been combined and presented under ORR; ANL-W and NRF have been combined with INEL; and SNL-CA has been combined with LLNL. Treatment risks at the remaining smaller sites are contained in the programwide risk tables presented in this section (Tables D.3.2–7 through D.3.2–19) and in the alternative summary risk tables presented in Section 7.4 of Volume I.

LLW may contain a wide range of radionuclides at activities ranging from trace amounts to thousands of curies. Depending on its chemical and physical properties, LLW can be grouped into waste stream categories according to the type of treatment needed, such as dilute and aqueous wastes; organic wastes; combustible wastes; noncombustible, compactible or noncompactible wastes; surface-contaminated bulk metal or equipment; activated bulk metal or equipment; sludges and resins; and remote-handled LLW (RH–LLW), a high-activity waste requiring special handling.

Currently, Hanford, INEL, LANL, NTS, ORR, and SRS are authorized to dispose of DOE-generated LLW. Low-activity wastes can be disposed of by shallow, engineered land disposal; higher-activity wastes require disposal technologies offering greater confinement.

Chapters 3 and 7 of the PEIS and the LLW technical report (ANL, 1996c) provide more detailed information on this waste, including LLW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, the process for developing PEIS LLW alternatives, and the various waste consolidation alternatives.

D.3.2.1 Summary of LLW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized 1 and 2, and Centralized) and the rationale for developing them are discussed rigorously in the main body of the PEIS. A broad range of alternatives are analyzed for this waste type:

- The No Action Alternative: All sites transport LLW to six sites (Hanford, INEL, LANL, NTS, ORR, and SRS) for disposal under current arrangements. All sites use existing treatment facilities.
- The Decentralized Alternative: Twelve sites dispose of all LLW projected to be generated over the next 20 years. Minimum treatment at each site is assumed.
- The Regionalized Alternatives (seven alternatives): Two, six, or ten sites dispose of all LLW projected to be generated over the next 20 years. In three of these alternatives, treatment to reduce waste volume (by shredding, compaction, and incineration) is performed.
- The Centralized Alternatives (five alternatives): One site (Hanford or NTS) disposes of all LLW projected to be generated over the next 20 years. In three of these alternatives, treatment to reduce volume is performed.

This series of alternatives makes it possible to compare the risks of minimum treatment versus minimum treatment plus volume reduction, the risks of using volume reduction at varying numbers of sites, and the risks associated with various disposal configurations. Table D.3.2–1 depicts the overall treatment and storage schemes for the LLW Alternatives.

D.3.2.2 Special Assumptions and Considerations Used in the LLW Risk Analysis

For all disposal scenarios, it is assumed that shallow land burial will be used at sites west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern sites. The exceptions are RFETS, which disposes in tumulus vaults, and SRS, which disposes in below-ground vaults.

Some LLW waste streams will already be disposed of onsite and are not considered in the consolidation alternatives. In particular, grout waste at Hanford and saltstone waste at SRS are not included in the LLW disposal inventories at their respective sites. Disposal of these waste forms is assumed to cause no risk to workers because the waste is piped directly into underground disposal facilities; therefore, worker risks have not been assessed for these situations.

It is assumed that, except in the No Action Alternative, LLW disposal capacity at each site will be expanded as required to meet disposal demands.

In estimating worker radiological risks, it is assumed that management and disposal of the "activated metals" and "remote-handled" categories of LLW require greater shielding for workers than the other categories because these two waste streams emit higher levels of external radiation; a remote shielding scenario was used to estimate worker radiation exposure, as described in ORNL unit risk methodology (ORNL, 1995c).

D.3.2.3 Results Tables for the LLW Human Health Risk Analysis

This section contains tables that summarize the results for the LLW human health risk analysis. A discussion of the results and the remainder of the results tables are presented in Section D.3.2.4. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.2–2 presents an overview, by alternative, of the *total*, programwide risks associated with treatment of LLW. Included are the risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste treatment. This table provides the estimated *total number* of people in the three populations who will develop or die of cancer caused by exposure to LLW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities. The results in this table are drawn from Tables D.3.2–7 through D.3.2–19 on the following pages.
- Table D.3.2–3 presents an overview, by alternative, of the programwide risks associated with disposal of LLW. This table summarizes the risks of cancer fatalities and cancer incidence for the maximally exposed lifetime (MEL) of the hypothetical farm family; the total risks to members of all 143 lifetimes of the farm family; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste disposal. The results in this table are drawn from Tables D.3.2–33 through D.3.2–46.
- Table D.3.2–4 shows the sizes of the total affected populations for each alternative.

- Table D.3.2–5 summarizes the risks to the noninvolved worker and offsite MEIs for each LLW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of cancer or develop cancer from radionuclide exposure. These results are drawn from Tables D.3.2–7 through D.3.2–19 and Tables D.3.2–33 through D.3.2–46.
- Table D.3.2–6 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population, by site and alternative.
- Tables D.3.2–46 through D.3.2–60 present programwide risks associated with disposal of LLW under each alternative, by site.

Table D.3.2–2. Summary of Programwide Risks Associated With Treatment of LLW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF	CI	CF	CI	CF	CI	C&OF
No Action	2.0E-03	7.0E-03	6.0E-05	2.0E-04	1.2	4.2	2.5
Minimum Treatment Alternatives							
Decentralized	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.3E-01	2.9	1.9
Regionalized 1	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.1E-01	2.8	1.9
Regionalized 3	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.1E-01	2.8	2.0
Regionalized 6	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.6E-01	3.0	2.2
Regionalized 7	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.6E-01	3.0	2.2
Centralized 1	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.6E-01	3.0	2.2
Centralized 2	2.9E-02	9.8E-02	1.9E-04	6.4E-04	8.6E-01	3.0	2.2
Volume Reduction Alternatives							
Regionalized 2	6.4E-01	2.2	6.6E-03	2.2E-02	1.3	4.5	3.9
Regionalized 4	9.7E-02	3.3E-01	1.9E-03	6.5E-03	1.5	5.0	3.9
Centralized 3	1.0E-01	3.4E-01	2.0E-03	7.0E-03	1.4	5.0	3.9
Centralized 4	1.0E-01	3.4E-01	2.0E-03	7.0E-03	1.4	5.0	3.9
Regionalized 5	3.7E-01	1.3	5.1E-03	1.7E-03	1.7	5.8	3.4
Centralized 5	9.8E-02	3.33E-01	1.1E-03	3.7E-03	2.3	7.7	4.1

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.2–3. Summary of Programwide Risks Associated With Disposal of LLW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative

Alternative	MEL of Farm Family		All (143) Lifetimes of Farm Family		WM Workers		
	CF	CI	CF	CI	CF	CI	C&OF
No Action	5.7E-03	2.0E-02	7.6E-02	2.6E-01	3.2	11	3.4
Decentralized Disposal							
Decentralized	6.7E-02	2.3E-01	1.3	4.5	2.6	9	5.5
Regionalized Disposal							
Regionalized 1	1.5E-03	5.1E-03	2.2E-02	7.4E-02	2.5	8.6	5.4
Regionalized 2	5.2E-03	1.8E-02	7.2E-02	2.5E-01	2.0	6.9	4.1
Regionalized 3	1.1E-03	3.9E-03	1.6E-02	5.3E-02	2.8	9.6	4.9
Regionalized 4	1.4E-02	4.7E-02	1.9E-01	6.2E-01	2.1	7.4	3.8
Regionalized 5	1.4E-02	4.7E-02	1.9E-01	6.2E-01	2.1	7.4	3.8
Regionalized 6	1.6E-02	5.6E-02	2.2E-01	7.3E-01	1.8	6.2	6.4
Regionalized 7	1.7E-04	5.9E-04	1.8E-04	6.3E-03	1.4	4.9	6.0
Centralized Disposal							
Centralized 1	4.8E-03	1.6E-02	6.4E-02	2.2E-01	2.8	9.7	1.4
Centralized 2	0.00	0.00	0.00	0.00	2.2	7.7	6.1E-01
Centralized 3	9.2E-03	3.1E-02	1.2E-01	4.2E-01	1.8	6.2	8.8E-01
Centralized 4	0.00	0.00	0.00	0.00	1.6	5.5	3.9E-01
Centralized 5	9.2E-03	3.1E-02	1.2E-01	4.2E-01	1.8	6.2	8.8E-01

Notes: CF = risk of cancer fatality associated with exposure to radionuclides; CI = risk of cancer incidence associated with exposure to radionuclides; C&OF = estimated construction and operational fatalities from physical hazards.

Table D.3.2-4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of LLW, by Alternative

Alternative	Offsite Population	Noninvolved Worker Population	WM Workers
No Action	44,304,014	123,959	17,433
Decentralized	44,304,014	123,959	10,191
Regionalized 1	44,304,014	123,959	10,389
Regionalized 3	44,304,014	123,959	10,737
Regionalized 6	44,304,014	123,959	11,833
Regionalized 7	44,304,014	123,959	12,055
Centralized 1	44,304,014	123,959	11,855
Centralized 2	44,304,014	123,959	12,077
Regionalized 2	47,068,603	126,415	21,443
Regionalized 4	44,304,014	123,959	21,823
Centralized 3	44,304,014	123,959	21,972
Centralized 4	44,304,014	123,959	21,972
Regionalized 5	44,304,014	123,959	19,989
Centralized 5	44,304,014	123,959	20,762

Table D.3.2-5. Summary of Programwide Risks Associated With Treatment of LLW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative

Alternative	Offsite MEI		Noninvolved Worker MEI	
	CF	CI	CF	CI
No Action	2.0E-08	6.9E-08	2.9E-08	9.7E-08
Decentralized	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Regionalized 1	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Regionalized 3	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Regionalized 6	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Regionalized 7	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Centralized 1	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Centralized 2	2.9E-07	9.7E-07	4.7E-08	1.6E-07
Regionalized 2	6.3E-06	2.1E-05	1.8E-06	6.2E-06
Regionalized 4	2.3E-06	7.9E-06	8.5E-07	2.9E-06
Centralized 3	2.3E-06	7.9E-06	6.3E-07	2.0E-06
Centralized 4	2.3E-06	7.9E-06	6.3E-07	2.0E-06
Regionalized 5	9.3E-06	3.2E-05	4.1E-06	1.4E-05
Centralized 5	1.5E-06	5.2E-06	1.7E-06	5.8E-06

Notes: MEI = maximally exposed individual; CF = risk of cancer fatality associated with exposure to radionuclides; CI = risk of cancer incidence associated with exposure to radionuclides.

Table D.3.2–6. Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLW Treatment, by Alternative and Site

Alt.	Site											
	ANL-E	BNL	FEMP	Hanford	INEL	KCP	KAPL-K	LBL	LLNL	LANL	Mound	
No Action	Pu-238[a] 7.0E-07[b]	Pu-238 6.5E-07		Pu-238 2.3E-07	Co-60 1.3E-06	U-238 5.5E-10	Co-60 5.3E-04	H-3 7.6E-04	U-238 2.4E-07	Pu-238 1.1E-04	Pu-238 4.3E-08	
Dec.	Pu-238 7.6E-07	Pu-238 8.5E-09		Pu-238 1.5E-06	Co-60 7.6E-07	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Reg. 1	Pu-238 7.6E-07	Pu-238 7.0E-07		Pu-238 1.5E-06	Co-60 7.6E-07	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Reg. 3	Pu-238 7.6E-07	Pu-238 7.0E-07		Pu-238 1.5E-06	Co-60 7.6E-07	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Reg. 6	Pu-238 7.6E-07	Pu-238 7.0E-07		Pu-238 1.5E-06	Co-60 1.2E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Reg. 7	Pu-238 7.6E-07	Pu-238 7.0E-07		Pu-238 2.2E-06	Co-60 1.2E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Cen. 1	Pu-238 7.6E-07	Pu-238 7.0E-07		Pu-238 1.5E-06	Co-60 1.2E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Cen. 2	Pu-238 7.6E-07	Pu-238 7.0E-07		Pu-238 2.2E-06	Co-60 1.2E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 1.0E-01	Pu-238 1.2E-04	Pu-238 4.7E-08	
Reg. 2	Pu-238 7.6E-07	Pu-238 7.0E-07	H-3 2.0E-01	Pu-238 1.9E-06	Co-60 1.3E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02	H-3 3.8E-01	U-238 1.0E-01	Pu-238 4.7E-08	
Reg. 4	Pu-238 7.6E-07	Pu-238 7.0E-07		H-3 5.0E-02	Co-60 1.3E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02		U-238 1.0E-01	Pu-238 4.7E-08	
Cen. 3 Cen. 4	Pu-238 7.6E-07	Pu-238 7.0E-07		H-3 5.0E-02	Co-60 1.3E-06	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02		U-238 1.0E-01	Pu-238 4.7E-08	
Reg. 5	Pu-238 7.6E-07	Pu-238 7.0E-07		H-3 5.0E-02	U-238 3.4E-04	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02		Pu-238 1.2E-04	Pu-238 4.7E-08	
Cen. 5	Pu-238 7.6E-07	Pu-238 7.0E-07		H-3 7.0E-02	Co-60 7.6E-07	U-238 5.7E-10	Co-60 5.2E-04	H-3 2.0E-02		Pu-238 1.2E-04	Pu-238 4.7E-08	
	NTS	K-25	ORNL	Y-12	PGDP	Pantex	Pinellas	PORTS	RFETS	SNL/NM	SRS	WVDP
No Action	Pu-238 2.4E-12	U-238 5.5E-08	Pu-238 2.7E-06	U-238 1.2E-08	U-238 1.8E-08	H-3 9.0E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 4.9E-08	U-238 8.8E-07	H-3 4.1E-04	Pu-238 2.1E-06
Dec.	Pu-238 2.6E-12	U-238 1.3E-07	Pu-238 2.9E-06	U-238 2.5E-08	U-238 2.8E-07	H-3 4.4E-07	H-3 1.8E-08	U-238 2.8E-10	Pu-238 1.4E-07	U-238 8.9E-07	H-3 6.2E-06	Pu-238 7.0E-07
Reg. 1	Pu-238 2.6E-12	U-238 1.3E-07	Pu-238 2.9E-06	U-238 2.5E-08	U-238 2.8E-07	H-3 4.4E-07	H-3 1.8E-08	U-238 2.8E-10	Pu-238 1.4E-07	U-238 9.1E-07	H-3 6.2E-06	Pu-238 1.2E-06
Reg. 3	Pu-238 2.6E-12	U-238 1.3E-07	Pu-238 2.9E-06	U-238 2.5E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	H-3 6.2E-06	Pu-238 1.2E-06
Reg. 6	Pu-238 3.0E-12	U-238 3.0E-07	U-238 3.5E-06	U-238 3.7E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	H-3 6.2E-06	Pu-238 1.2E-06
Reg. 7	Pu-238 2.6E-12	U-238 3.0E-07	U-238 3.5E-06	U-238 3.7E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	H-3 6.2E-06	Pu-238 1.2E-06
Cen. 1	Pu-238 3.0E-12	U-238 3.0E-07	U-238 3.5E-06	U-238 3.7E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	H-3 6.2E-06	Pu-238 1.2E-06
Cen. 2	Pu-238 2.6E-12	U-238 3.0E-07	U-238 3.5E-06	U-238 3.7E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	H-3 6.2E-06	Pu-238 1.2E-06
Reg. 2	Pu-238 3.0E-12	U-238 5.5E-08	U-238 6.5E-05	U-238 1.3E-08	U-238 1.6E-06	H-3 4.4E-07	H-3 1.8E-08	Co-60 5.8E-05	Pu-238 7.4E-05	U-238 9.1E-07	H-3 4.1E-04	Pu-238 1.2E-06
Reg. 4	Pu-238 3.0E-12	U-238 5.5E-08	U-238 6.5E-05	U-238 1.3E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	H-3 2.0E-01	Pu-238 7.4E-05	U-238 9.1E-07	H-3 4.1E-04	Pu-238 1.2E-06
Cen. 3 Cen. 4	Pu-238 3.0E-12	U-238 7.5E-08	U-238 6.5E-05	U-238 1.6E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	H-3 2.0E-01	Pu-238 7.4E-05	U-238 9.1E-07	H-3 4.1E-04	Pu-238 1.2E-06
Reg. 5	Pu-238 3.0E-12	U-238 5.5E-08	H-3 3.0E-01	U-238 1.3E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	H-3 4.1E-04	Pu-238 1.2E-06
Cen. 5	Pu-238 3.0E-12	U-238 3.0E-07	U-238 3.5E-06	U-238 3.7E-08	U-238 1.8E-08	H-3 4.4E-07	H-3 1.8E-08	U-238 1.6E-09	Pu-238 1.6E-07	U-238 9.1E-07	Co-60 5.0E-6	Pu-238 1.2E-06

Notes: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; and Cen. = Centralized.
[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

Table D.3.2-7. Programwide Risks Associated With Treatment of LLW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	1.0E-01	
	Cancer Fatalities	6.0E-05	
	Cancer incidence	2.0E-04	
	Genetic effects	1.0E-05	
Noninvolved worker MEI	Dose (rem)	5.7E-05	
	Cancer Fatalities	2.9E-08	
	Cancer incidence	9.7E-08	
	Genetic effects	5.7E-09	
	Hazard index		
Offsite population	Dose (person-rem)	5.0E+00	
	Cancer Fatalities	2.0E-03	
	Cancer incidence	7.0E-03	
	Genetic effects	5.0E-04	
Offsite MEI	Dose (rem)	4.1E-05	
	Cancer Fatalities	2.0E-08	
	Cancer incidence	6.9E-08	
	Genetic effects	4.1E-09	
	Hazard index		
WM workers	Dose (FTE-rem)	2.9E+03	
	Cancer Fatalities	1.2E+00	
	Cancer incidence	4.2	
	Genetic effects	1.8E-01	
	Exposure index		
	Construction fatalities		8.2E-01
	Construction injuries		3.3E+02
	Operation fatalities		1.7
	Operation injuries		1.3E+03

Table D.3.2-8. Programwide Risks Associated With Treatment of LLW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E-01	
	Cancer fatalities	1.9E-04	
	Cancer incidence	6.4E-04	
	Genetic effects	3.7E-05	
Noninvolved worker MEI	Dose (rem)	9.5E-05	
	Cancer fatalities	4.7E-08	
	Cancer incidence	1.6E-07	
	Genetic effects	9.5E-09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E-02	
	Cancer incidence	9.8E-02	
	Genetic effects	5.8E-03	
Offsite MEI	Dose (rem)	5.7E-04	
	Cancer fatalities	2.9E-07	
	Cancer incidence	9.7E-07	
	Genetic effects	5.7E-08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.1E+03	
	Cancer fatalities	8.3E-01	
	Cancer incidence	2.9	
	Genetic effects	1.2E-01	
	Exposure index		
	Construction fatalities		9.2E-01
	Construction injuries		3.7E+02
	Operation fatalities		9.9E-01
	Operation injuries		7.6E+02

Table D.3.2–9. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E–01	
	Cancer fatalities	1.9E–04	
	Cancer incidence	6.4E–04	
	Genetic effects	3.7E–05	
Noninvolved worker MEI	Dose (rem)	9.4E–05	
	Cancer fatalities	4.7E–08	
	Cancer incidence	1.6E–07	
	Genetic effects	9.4E–09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E–02	
	Cancer incidence	9.8E–02	
	Genetic effects	5.8E–03	
Offsite MEI	Dose (rem)	5.7E–04	
	Cancer fatalities	2.9E–07	
	Cancer incidence	9.7E–07	
	Genetic effects	5.7E–08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.0E+03	
	Cancer fatalities	8.1E–01	
	Cancer incidence	2.8	
	Genetic effects	1.2E–01	
	Exposure index		
	Construction fatalities		9.3E–01
	Construction injuries		3.8E+02
	Operation fatalities		1.0
	Operation injuries		7.6E+02

Table D.3.2–10. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E–01	
	Cancer fatalities	1.9E–04	
	Cancer incidence	6.4E–04	
	Genetic effects	3.7E–05	
Noninvolved worker MEI	Dose (rem)	9.4E–05	
	Cancer fatalities	4.7E–08	
	Cancer incidence	1.6E–07	
	Genetic effects	9.4E–09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E–02	
	Cancer incidence	9.8E–02	
	Genetic effects	5.8E–03	
Offsite MEI	Dose (rem)	5.7E–04	
	Cancer fatalities	2.9E–07	
	Cancer incidence	9.7E–07	
	Genetic effects	5.7E–08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.0E+03	
	Cancer fatalities	8.1E–01	
	Cancer incidence	2.8	
	Genetic effects	1.2E–01	
	Exposure index		
	Construction fatalities		9.4E–01
	Construction injuries		3.9E+02
	Operation fatalities		1.1
	Operation injuries		8.4E+02

Table D.3.2–11. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 6, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E–01	
	Cancer fatalities	1.9E–04	
	Cancer incidence	6.4E–04	
	Genetic effects	3.7E–05	
Noninvolved worker MEI	Dose (rem)	9.5E–05	
	Cancer fatalities	4.7E–08	
	Cancer incidence	1.6E–07	
	Genetic effects	9.5E–09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E–02	
	Cancer incidence	9.8E–02	
	Genetic effects	5.8E–03	
Offsite MEI	Dose (rem)	5.7E–04	
	Cancer fatalities	2.9E–07	
	Cancer incidence	9.7E–07	
	Genetic effects	5.7E–08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.1E+03	
	Cancer fatalities	8.6E–01	
	Cancer incidence	3.0	
	Genetic effects	1.3E–01	
	Exposure index		
	Construction fatalities		1.1
	Construction injuries		4.3E+02
	Operation fatalities		1.1
	Operation injuries		8.8E+02

Table D.3.2-12. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 7, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E-01	
	Cancer fatalities	1.9E-04	
	Cancer incidence	6.4E-04	
	Genetic effects	3.7E-05	
Noninvolved worker MEI	Dose (rem)	9.5E-05	
	Cancer fatalities	4.7E-08	
	Cancer incidence	1.6E-07	
	Genetic effects	9.5E-09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E-02	
	Cancer incidence	9.8E-02	
	Genetic effects	5.8E-03	
Offsite MEI	Dose (rem)	5.7E-04	
	Cancer fatalities	2.9E-07	
	Cancer incidence	9.7E-07	
	Genetic effects	5.7E-08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.1E+03	
	Cancer fatalities	8.6E-01	
	Cancer incidence	3.0	
	Genetic effects	1.3E-01	
	Exposure index		
	Construction fatalities		1.1
	Construction injuries		4.5E+02
	Operation fatalities		1.1
	Operation injuries		8.8E+02

Table D.3.2–13. Programwide Risks Associated With Treatment of LLW Under the Centralized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E–01	
	Cancer fatalities	1.9E–04	
	Cancer incidence	6.4E–04	
	Genetic effects	3.7E–05	
Noninvolved worker MEI	Dose (rem)	9.5E–05	
	Cancer fatalities	4.7E–08	
	Cancer incidence	1.6E–07	
	Genetic effects	9.5E–09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E–02	
	Cancer incidence	9.8E–02	
	Genetic effects	5.8E–03	
Offsite MEI	Dose (rem)	5.7E–04	
	Cancer fatalities	2.9E–07	
	Cancer incidence	9.7E–07	
	Genetic effects	5.7E–08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.1E+03	
	Cancer fatalities	8.6E–01	
	Cancer incidence	3	
	Genetic effects	1.3E–01	
	Exposure index		
	Construction fatalities		1.1
	Construction injuries		4.3E+02
	Operation fatalities		1.1
	Operation injuries		8.8E+02

Table D.3.2–14. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.7E–01	
	Cancer fatalities	1.9E–04	
	Cancer incidence	6.4E–04	
	Genetic effects	3.7E–05	
Noninvolved worker MEI	Dose (rem)	9.5–05	
	Cancer fatalities	4.7E–08	
	Cancer incidence	1.6E–07	
	Genetic effects	9.5E–09	
	Hazard index		
Offsite population	Dose (person-rem)	5.8E+01	
	Cancer fatalities	2.9E–02	
	Cancer incidence	9.8E–02	
	Genetic effects	5.8E–03	
Offsite MEI	Dose (rem)	5.7E–04	
	Cancer fatalities	2.9E–07	
	Cancer incidence	9.7E–07	
	Genetic effects	5.7E–08	
	Hazard index		
WM workers	Dose (FTE-rem)	2.1E+03	
	Cancer fatalities	8.6E–01	
	Cancer incidence	3.0	
	Genetic effects	1.3E–01	
	Exposure index		
	Construction fatalities		1.1
	Construction injuries		4.5E+02
	Operation fatalities		1.1
	Operation injuries		8.8E+02

Table D.3.2-15. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	1.3E+01	
	Cancer fatalities	6.6E-03	
	Cancer incidence	2.2E-02	
	Genetic effects	1.3E-03	
Noninvolved worker MEI	Dose (rem)	3.6E-03	
	Cancer fatalities	1.8E-06	
	Cancer incidence	6.2E-06	
	Genetic effects	3.6E-07	
	Hazard index		
Offsite population	Dose (person-rem)	1.3E+03	
	Cancer fatalities	6.4E-01	
	Cancer incidence	2.2	
	Genetic effects	1.3E-01	
Offsite MEI	Dose (rem)	1.3E-02	
	Cancer fatalities	6.3E-06	
	Cancer incidence	2.1E-05	
	Genetic effects	1.3E-06	
	Hazard index		
WM workers	Dose (FTE-rem)	3.2E+03	
	Cancer fatalities	1.3	
	Cancer incidence	4.5	
	Genetic effects	2.0E-01	
	Exposure index		
	Construction fatalities		1.8
	Construction injuries		7.3E+02
	Operation fatalities		2.1
	Operation injuries		1.6E+03

Table D.3.2–16. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	3.8	
	Cancer fatalities	1.9E–03	
	Cancer incidence	6.5E–03	
	Genetic effects	3.8E–04	
Noninvolved worker MEI	Dose (rem)	1.7E–03	
	Cancer fatalities	8.5E–07	
	Cancer incidence	2.9E–06	
	Genetic effects	1.7E–07	
	Hazard index		
Offsite population	Dose (person-rem)	2.0E+02	
	Cancer fatalities	9.7E–02	
	Cancer incidence	3.3E–01	
	Genetic effects	2.0E–02	
Offsite MEI	Dose (rem)	4.6E–03	
	Cancer fatalities	2.3E–06	
	Cancer incidence	7.9E–06	
	Genetic effects	4.6E–07	
	Hazard index		
WM workers	Dose (FTE-rem)	3.6E+03	
	Cancer fatalities	1.5	
	Cancer incidence	5.0	
	Genetic effects	2.1E–01	
	Exposure index		
	Construction fatalities		1.8
	Construction injuries		7.5E+02
	Operation fatalities		2.1
	Operation injuries		1.6E+03

Table D.3.2–17. Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	4.1	
	Cancer fatalities	2.0E–03	
	Cancer incidence	7.0E–03	
	Genetic effects	4.1E–04	
Noninvolved worker MEI	Dose (rem)	1.2E–03	
	Cancer fatalities	6.3E–07	
	Cancer incidence	2.0E–06	
	Genetic effects	1.2E–07	
	Hazard index		
Offsite population	Dose (person-rem)	2.0E+02	
	Cancer fatalities	1.0E–01	
	Cancer incidence	3.4E–01	
	Genetic effects	2.0E–02	
Offsite MEI	Dose (rem)	4.6E–03	
	Cancer fatalities	2.3E–06	
	Cancer incidence	7.9E–06	
	Genetic effects	4.6E–07	
	Hazard index		
WM workers	Dose (FTE-rem)	3.6E+03	
	Cancer fatalities	1.4	
	Cancer incidence	5.0	
	Genetic effects	2.2E–01	
	Exposure index		
	Construction fatalities		1.8
	Construction injuries		7.5E+02
	Operation fatalities		2.1
	Operation injuries		1.6E+03

Table D.3.2-18. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	1.0E+01	
	Cancer fatalities	5.1E-03	
	Cancer incidence	1.7E-02	
	Genetic effects	1.0E-03	
Noninvolved worker MEI	Dose (rem)	8.3E-03	
	Cancer fatalities	4.1E-06	
	Cancer incidence	1.4E-05	
	Genetic effects	8.3E-07	
	Hazard index		
Offsite population	Dose (person-rem)	7.5E+02	
	Cancer fatalities	3.7E-01	
	Cancer incidence	1.3	
	Genetic effects	7.5E-02	
Offsite MEI	Dose (rem)	1.9E-02	
	Cancer fatalities	9.3E-06	
	Cancer incidence	3.2E-05	
	Genetic effects	1.9E-06	
	Hazard index		
WM workers	Dose (FTE-rem)	4.2E+03	
	Cancer fatalities	1.7	
	Cancer incidence	5.8	
	Genetic effects	2.5E-01	
	Exposure index		
	Construction fatalities		1.6
	Construction injuries		6.3E+02
	Operation fatalities		1.8
	Operation injuries		1.3E+03

Table D.3.2–19. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Noninvolved worker population	Dose (person-rem)	2.2	
	Cancer fatalities	1.1E–03	
	Cancer incidence	3.7E–03	
	Genetic effects	2.2E–04	
Noninvolved worker MEI	Dose (rem)	3.4E–03	
	Cancer fatalities	1.7E–06	
	Cancer incidence	5.8E–06	
	Genetic effects	3.4E–07	
	Hazard index		
Offsite population	Dose (person-rem)	2.0E+02	
	Cancer fatalities	9.8E–02	
	Cancer incidence	3.3E–01	
	Genetic effects	2.0E–02	
Offsite MEI	Dose (rem)	3.1E–03	
	Cancer fatalities	1.5E–06	
	Cancer incidence	5.2E–06	
	Genetic effects	3.1E–07	
	Hazard index		
WM workers	Dose (FTE-rem)	5.5E+03	
	Cancer fatalities	2.3	
	Cancer incidence	7.7	
	Genetic effects	3.2E–01	
	Exposure index		
	Construction fatalities		1.9
	Construction injuries		8.0E+02
	Operation fatalities		2.2
	Operation injuries		1.8E+03

Table D.3.2-20. Programwide Risks Associated With Treatment of LLW Under the No Action Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
INEL	153,061 2,169	1.4E-06	1.7E-10	6.1E-01	4.7E-06	5.8E-10	8.7E-01
Hanford	377,645 997	4.2E-07	8.6E-12	3.2E-01	1.4E-06	2.9E-11	5.4E-01
KAPL-K	1,290,172 925	5.3E-04	1.2E-08	1.7E-01	1.8E-03	4.0E-08	1.8E-02
LBL	5,856,829 236	7.6E-04	1.2E-08	5.1E-02	2.6E-03	4.1E-08	2.9E-02
LANL	159,152 920	1.9E-04	2.0E-08	3.3E-01	6.6E-04	6.9E-08	6.2E-01
NTS	14,266 78	1.3E-12	3.3E-16	5.4E-03	4.5E-12	1.1E-15	1.3E-03
ORNL	881,652 893	4.6E-06	1.4E-10	1.9E-01	1.6E-05	4.9E-10	3.9E-01
SNL-NM	610,714 277	1.7E-06	6.8E-11	5.1E-02	5.8E-06	2.3E-10	1.8E-03
SRS	620,618 3,032	5.9E-04	5.6E-09	8.5E-01	2.0E-03	1.9E-08	1.2
KCP	1,729,833 13	1.0E-09	4.6E-14	2.4E-03	3.4E-09	1.6E-13	1.3E-04
LLNL	6,324,234 426	3.5E-07	5.8E-12	7.0E-02	1.2E-06	2.0E-11	4.1E-03
Mound	3,032,983 710	9.4E-08	5.5E-12	1.4E-01	3.2E-07	1.9E-11	7.2E-03
K-25	871,406 1,278	5.8E-08	1.3E-12	8.0E-02	2.0E-07	4.3E-12	2.3E-02
Y-12	895,379 724	1.3E-08	4.9E-13	5.7E-02	4.5E-08	1.7E-12	9.7E-03
PGDP	500,502 654	2.0E-08	2.3E-12	1.2E-01	6.9E-08	7.6E-12	7.8E-03
Pantex	265,185 333	8.8E-07	7.5E-11	3.0E-02	3.0E-06	2.5E-10	3.4E-03
Pinellas	2,532,174 26	1.8E-08	3.8E-13	4.7E-03	6.0E-08	1.3E-12	2.4E-04
PORTS	639,602 1,450	1.7E-09	2.1E-13	2.5E-01	5.7E-09	7.2E-13	2.0E-02
RFETS	2,171,877 656	1.2E-07	1.7E-12	1.2E-01	4.1E-07	5.6E-12	6.5E-03
ANL-E	7,939,785 402	2.3E-06	1.3E-11	1.1E-01	8.0E-06	4.4E-11	1.5E-01
BNL	5,738,554 695	2.2E-06	2.9E-11	1.1E-01	7.4E-06	9.9E-11	2.1E-01
WVDP	1,698,391 539	3.5E-06	5.3E-11	5.7E-02	1.2E-05	1.8E-10	6.5E-02
Total		2.0E-03	2.0E-08	3.7	7.0E-03	6.9E-08	4.2

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-21. Programwide Risks Associated With Treatment of LLW Under the Decentralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
Hanford	377,645 577	2.7E-06	5.5E-11	2.2E-01	9.1E-06	1.9E-10	3.5E-01
INEL	153,061 677	8.0E-07	9.9E-11	3.2E-01	2.7E-06	3.4E-10	5.8E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LLNL	6,324,234 191	1.0E-02	1.6E-07	5.0E-02	3.4E-02	5.5E-07	8.9E-03
LANL	159,152 653	2.1E-04	2.2E-08	2.8E-01	7.1E-04	7.5E-08	4.9E-01
ORNL	881,652 347	5.0E-06	1.56E-10	1.09E-01	1.71E-05	5.31E-10	2.13E-01
SNL-NM	610,714 187	1.8E-06	7.1E-11	6.5E-02	6.1E-06	2.4E-10	7.6E-02
SRS	620,618 1,986	1.9E-05	1.7E-10	6.6E-01	6.3E-05	5.9E-10	7.9E-01
BNL	5,738,554 273	9.66E-09	1.29E-13	5.8E-02	3.28E-08	4.38E-13	1.27E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,042	1.33E-07	2.9E-12	9.0E-02	4.53E-07	9.97E-12	1.87E-02
Y-12	895,379 503	2.6E-08	9.7E-13	5.4E-02	8.9E-08	3.3E-12	7.1E-03
PGDP	500,502 501	3.2E-07	3.6E-11	1.1E-01	1.1E-06	1.2E-10	5.2E-03
Pantex	265,185 214	4.38E-07	3.73E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 730	2.4E-10	3.1E-14	1.5E-01	8.3E-10	1.1E-13	1.6E-02
RFETS	2,171,877 298	3.6E-07	4.9E-12	7.1E-02	1.2E-06	1.7E-11	4.0E-03
NTS	14,266 64	1.43E-12	3.62E-16	6.5E-03	4.86E-12	1.23E-15	1.03E-03
WVDP	1,698,391 433	1.24E-06	1.86E-11	6.2E-02	4.2E-06	6.3E-11	4.5E-02
Total		2.9E-02	2.9E-07	2.7	9.9E-02	9.7E-07	2.9

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-22. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 1, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 577	2.7E-06	5.5E-11	2.2E-01	9.1E-06	1.9E-10	3.5E-01
INEL	153,061 677	8.0E-07	9.9E-11	3.2E-01	2.7E-06	3.4E-10	5.8E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LLNL	6,324,234 191	1.0E-02	1.6E-07	5.0E-02	3.4E-02	5.5E-07	8.9E-03
LANL	159,152 653	2.1E-04	2.2E-08	2.8E-01	7.1E-04	7.5E-08	4.9E-01
ORNL	881,652 347	5.0E-06	1.6E-10	1.1E-01	1.7E-05	5.3E-10	2.1E-01
PORTS	639,602 730	2.4E-10	3.1E-14	1.5E-01	8.3E-10	1.1E-13	1.6E-02
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 1,986	1.9E-05	1.7E-10	6.6E-01	6.3E-05	5.9E-10	7.9E-01
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,042	1.3E-07	2.9E-12	9.0E-02	4.5E-07	1.0E-11	1.9E-02
Y-12	895,379 503	2.6E-08	9.7E-13	5.4E-02	8.9E-08	3.3E-12	7.1E-03
PGDP	500,502 501	3.2E-07	3.6E-11	1.1E-01	1.1E-06	1.2E-10	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
RFETS	2,171,877 298	3.6E-07	4.9E-12	7.1E-02	1.2E-06	1.7E-11	4.0E-03
NTS	14,266 64	1.4E-12	3.6E-16	6.5E-03	4.9E-12	1.2E-15	1.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.0E-10	1.4E-01
WVDP	1,698,391 464	2.1E-06	3.1E-11	6.6E-02	7.0E-06	1.0E-10	4.5E-02
Total		2.9E-02	2.9E-07	2.8	9.8E-02	9.7E-07	2.8

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–23. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 3, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 577	2.7E-06	5.5E-11	2.2E-01	9.1E-06	1.9E-10	3.5E-01
INEL	153,061 677	8.0E-07	9.9E-11	3.2E-01	2.7E-06	3.4E-10	5.8E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 653	2.1E-04	2.2E-08	2.8E-01	7.1E-04	7.5E-08	4.9E-01
NTS	14,266 0	0.00	0.00	0.00	0.00	0.00	0.00
ORNL	881,652 266	5.0E-06	1.6E-10	8.9E-02	1.7E-05	5.3E-10	2.1E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 1,986	1.9E-05	1.7E-10	6.6E-01	6.3E-05	5.9E-10	7.9E-01
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	1.0E-02	1.6E-07	5.9E-02	3.4E-02	5.5E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,042	1.3E-07	2.9E-12	9.0E-02	4.5E-07	1.0E-11	1.9E-02
Y-12	895,379 503	2.6E-08	9.7E-13	5.4E-02	8.9E-08	3.3E-12	7.1E-03
PGDP	500,502 503	2.1E-08	9.7E-13	5.4E-02	8.9E-08	3.3E-12	7.1E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 1,075	1.8E-09	2.2E-13	2.3E-01	6.0E-09	7.5E-13	1.6E-02
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
NTS	14,266 64	1.4E-12	3.6E-16	6.4E-03	4.9E-12	1.2E-15	1.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9-06	1.0E-10	1.4E-01
WVDP	1,698,391 464	2.1E-06	3.1E-11	6.6E-02	7.0E-06	1.0E-10	4.5E-02
Total		2.9E-02	2.9E-07	2.8	9.8E-02	9.7E-07	2.8

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-24. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 6, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 577	2.7E-06	5.5E-11	2.2E-01	9.1E-06	1.9E-10	3.5E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 902	2.1E-04	2.2E-08	3.3E-01	7.1E-04	7.5E-08	4.9E-01
ORNL	881,652 382	1.2E-05	3.5E-10	1.2E-01	3.9E-05	1.2E-09	2.5E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 1,986	1.9E-05	1.7E-10	6.6E-01	6.3E-05	5.9E-10	7.9E-01
INEL	153,061 1,032	1.3E-06	1.6E-10	4.3E-01	4.4E-06	5.4E-10	7.2E-01
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	1.0E-02	1.6E-07	5.9E-02	3.4E-02	5.5E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,259	3.2E-07	7.0E-12	1.2E-01	1.1E-06	2.4E-11	1.9E-02
Y-12	895,379 618	4.0E-08	1.5E-12	6.7E-02	1.4E-07	5.0E-12	7.1E-03
PGDP	500,502 503	2.1E-08	2.3E-12	1.1E-01	7.1E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 1,075	1.8E-09	2.2E-13	2.3E-01	6.0E-09	7.5E-13	1.6E-02
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
NTS	14,266 108	1.6E-12	4.1E-16	1.3E-02	5.5E-12	1.4E-15	1.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.0E-10	1.4E-01
WVDP	1,698,391 464	2.1E-06	3.1E-11	6.6E-02	7.0E-06	1.0E-10	4.5E-02
Total		2.9E-02	2.9E-07	3.1	9.8E-02	9.7E-07	3.0

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–25. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 7, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 843	4.2E-06	8.5E-11	2.9E-01	1.4E-05	2.9E-10	3.6E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 902	2.1E-04	2.2E-08	3.3E-01	7.1E-04	7.5E-08	4.9E-01
NTS	14,266 64	1.4E-12	3.6E-16	6.5E-03	4.9E-12	1.2E-15	1.0E-03
ORNL	881,652 382	1.2E-05	3.5E-10	1.2E-01	3.9E-05	1.2E-09	2.5E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 1,986	1.9E-05	1.7E-10	6.6E-01	6.3E-05	5.9E-10	7.9E-01
INEL	153,061 1,032	1.3E-06	1.6E-10	4.3E-01	4.4E-06	5.4E-10	7.2E-01
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	1.0E-02	1.6E-07	5.9E-02	3.4E-02	5.5E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,259	3.2E-07	7.0E-12	1.2E-01	1.1E-06	2.4E-11	1.9E-02
Y-12	895,379 618	4.0E-08	1.5E-12	6.7E-02	1.4E-07	5.0E-12	7.10E-03
PGDP	500,502 503	2.1E-08	2.3E-12	1.1E-01	7.1E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 1,075	1.8E-09	2.2E-13	2.3E-01	6.0E-09	7.5E-13	1.6E-02
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.0E-10	1.40E-01
WVDP	1,698,391 464	2.1E-06	3.1E-11	6.6E-02	7.0E-06	1.0E-10	4.5E-02
Total		2.9E-02	2.9E-07	3.1	9.8E-02	9.7E-07	3.0

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-26. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 1, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 577	2.7E-06	5.5E-11	2.2E-01	9.1E-06	1.9E-10	3.5E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 902	2.1E-04	2.2E-08	3.3E-01	7.1E-04	7.5E-08	4.9E-01
ORNL	881,652 382	1.2E-05	3.5E-10	1.2E-01	3.9E-05	1.2E-09	2.5E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 2,008	1.9E-05	1.8E-10	6.7E-01	6.3E-05	5.9E-10	8.0E-01
INEL	153,061 1,032	1.3E-06	1.6E-10	4.3E-01	4.4E-06	5.4E-10	7.2E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	1.0E-02	1.6E-07	5.9E-02	3.4E-02	5.5E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,259	3.2E-07	7.0E-12	1.2E-01	1.1E-06	2.4E-11	1.9E-02
Y-12	895,379 618	4.0E-08	1.5E-12	6.7E-02	1.4E-07	5.0E-12	7.10E-03
PGDP	500,502 503	2.1E-08	2.3E-12	1.1E-01	7.1E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 1,075	1.8E-09	2.2E-13	2.3E-01	6.0E-09	7.5E-13	1.6E-02
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.1E-10	1.4E-01
WVDP	1,698,391 464	2.1E-06	3.1E-11	6.6E-02	7.0E-06	1.0E-10	4.5E-02
NTS	14,266 108	1.6E-12	4.1E-16	1.3E-02	5.5E-12	1.4E-15	1.0E-03
Total		2.9E-02	2.9E-07	3.1	9.8E-02	9.7E-07	3.0

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-27. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 2, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 843	4.2E-06	8.5E-11	2.9E-01	1.4E-05	2.9E-10	3.6E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 902	2.1E-04	2.2E-08	3.3E-01	7.1E-04	7.5E-08	4.9E-01
NTS	14,266 64	1.4E-12	3.6E-16	6.5E-03	4.9E-12	1.2E-15	1.0E-03
ORNL	881,652 382	1.2E-05	3.5E-10	1.2E-01	3.9E-05	1.2E-09	2.5E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 2,008	1.9E-05	1.8E-10	6.7E-01	6.3E-05	5.9E-10	8.0E-01
INEL	153,061 1,032	1.3E-06	1.6E-10	4.3E-01	4.4E-06	5.4E-10	7.2E-01
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	1.0E-02	1.6E-07	5.9E-02	3.4E-02	5.5E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,259	3.2E-07	7.0E-12	1.2E-01	1.1E-06	2.4E-11	1.9E-02
Y-12	895,379 618	4.0E-08	1.5E-12	6.7E-02	1.4E-07	5.0E-12	7.1E-03
PGDP	500,502 503	2.1E-08	2.3E-12	1.1E-01	7.1E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 1,075	1.8E-09	2.2E-13	2.3E-01	6.0E-09	7.5E-13	1.6E-02
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.1E-10	1.4E-01
WVDP	1,698,391 464	2.1E-06	3.1E-11	6.6E-02	7.0E-06	1.0E-10	4.5E-02
Total		2.9E-02	2.9E-07	3.1	9.8E-02	9.7E-07	3.0

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–28. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 2, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Fernald	2,764,589 461	2.3E-01	4.4E-06	1.2E-01	7.9E-01	1.5E-05	2.3E-02
Hanford	377,645 1,569	3.6E-06	7.3E-11	5.2E-01	1.2E-05	2.5E-10	6.9E-01
INEL	153,061 1,809	1.4E-06	1.7E-10	5.4E-01	4.6E-06	5.7E-10	5.8E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LLNL	6,324,234 483	3.9E-01	6.3E-06	1.5E-01	1.3	2.1E-05	1.7E-01
LANL	159,152 1,362	7.8E-03	8.2E-07	4.9E-01	2.7E-02	2.8E-06	6.5E-01
ORNL	881,652 3,660	8.2E-05	2.5E-09	6.9E-01	2.8E-04	8.5E-09	1.1
PORTS	639,602 3,434	5.3E-05	6.6E-09	7.4E-01	1.8E-04	2.2E-08	9.6E-02
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 2,598	6.1E-04	5.7E-09	8.3E-01	2.1E-03	2.0E-08	9.6E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
RFETS	2,171,877 800	1.9E-04	2.5E-09	2.2E-01	6.3E-04	8.6E-09	4.0E-03
K-25	871,406 1,040	6.1E-08	1.3E-12	8.9E-02	2.1E-07	4.5E-12	1.9E-02
Y-12	895,379 498	1.4E-08	5.1E-13	5.4E-02	4.7E-08	1.7E-12	7.1E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
Pantex	265,185 216	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
PGDP	500,502 800	1.9E-06	2.1E-10	1.9E-01	6.4E-06	7.1E-10	5.8E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.1E-10	1.4E-01
WVDP	1,698,391 463	2.1E-06	3.1E-11	6.6E-02	7.2E-06	1.1E-10	4.5E-02
NTS	14,266 108	1.6E-12	4.1E-16	1.3E-02	5.5E-12	1.4E-5	1.0E-03
Total		6.4E-01	6.3E-06	5.2	2.2	2.1E-05	4.6

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-29. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 1,634	4.7E-02	9.6E-07	5.4E-01	1.6E-01	3.3E-06	7.2E-01
INEL	153,061 1,809	1.4E-06	1.7E-10	5.4E-01	4.6E-06	5.7E-10	5.8E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 2,731	7.8E-03	8.2E-07	9.3E-01	2.7E-02	2.8E-06	1.2
ORNL	881,652 3,579	8.2E-05	2.5E-09	6.7E-01	2.8E-04	8.5E-09	1.1
PORTS	639,602 3,483	1.9E-02	2.3E-06	7.6E-01	6.4E-02	7.9E-06	1.3E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 2,598	6.1E-04	5.7E-09	8.3E-01	2.1E-03	2.0E-08	9.6E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	4.4E-03	7.1E-08	5.9E-02	1.5E-02	2.4E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
NTS	14,266 108	1.6E-12	4.1E-16	1.3E-02	5.5E-12	1.4E-15	1.0E-03
K-25	871,406 1,040	6.1E-08	1.3E-12	8.9E-02	2.1E-07	4.5E-12	1.9E-02
Y-12	895,379 498	1.4E-08	5.1E-13	5.4E-02	4.7E-08	1.7E-12	7.1E-03
PGDP	500,502 497	2.1E-08	2.4E-12	1.1E-01	7.2E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
RFETS	2,171,877 800	1.9E-04	2.5E-09	2.2E-01	6.3E-04	8.6E-09	4.0E-03

Table D.3.2-29. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 4, by Site—Continued

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.1E-10	1.4E-01
WVDP	1,698,391 463	2.1E-06	3.1E-11	6.6E-02	7.2E-06	1.1E-10	4.5E-02
Total		9.7E-02	2.3E-06	5.4	3.3E-01	7.9E-06	5.1

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–30. Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 1,634	5.0E-02	1.0E-06	5.4E-01	1.7E-01	3.5E-06	7.2E-01
INEL	153,061 1,809	1.4E-06	1.7E-10	5.4E-01	4.6E-06	5.7E-10	5.8E-01
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 2,731	7.8E-03	8.2E-07	9.3E-01	2.7E-02	2.8E-06	1.2
NTS	14,266 108	1.6E-12	4.1E-16	1.3E-02	5.5E-12	1.4E-15	1.0E-03
ORNL	881,652 3,695	8.9E-05	2.7E-09	7.1E-01	3.0E-04	9.2E-09	1.1
PORTS	639,602 3,481	1.9E-02	2.3E-06	7.6E-01	6.4E-02	7.9E-06	1.3E-01
SNL-NM	610,714 232	1.8E-06	7.2E-11	7.7E-02	6.2E-06	2.4E-10	7.6E-02
SRS	620,618 2,598	6.1E-04	5.7E-09	8.3E-01	2.1E-03	2.0E-08	9.6E-01
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
LLNL	6,324,234 227	4.4E-03	7.1E-08	5.9E-02	1.5E-02	2.4E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,044	8.2E-08	1.8E-12	9.0E-02	2.8E-07	6.1E-12	1.9E-02
Y-12	895,379 507	1.7E-08	6.3E-13	5.5E-02	5.8E-08	2.2E-12	7.1E-03
PGDP	500,502 497	2.1E-08	2.4E-12	1.1E-01	7.2E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04

Table D.3.2-30. Programwide Risks Associated With Treatment of LLW Under Centralized Alternatives 3 and 4, by Site—Continued

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
RFETS	2,171,877 800	1.9E-04	2.5E-09	2.2E-01	6.3E-04	8.6E-09	4.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.E-10	1.4E-01
WVDP	1,698,391 463	2.1E-06	3.1E-11	6.6E-02	7.2E-06	1.E-10	4.5E-02
Total		1.0E-01	2.3E-06	5.4	3.4E-01	7.9E-06	5.1

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–31. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 1,634	4.7E–02	9.6E–07	5.4E–01	1.6E–01	3.3E–06	7.2E–01
INEL	153,061 3,954	4.1E–04	5.1E–08	1.3	1.4E–03	1.7E–07	1.9
KAPL-K	1,290,172 650	5.3E–04	1.2E–08	1.5E–01	1.8E–03	4.0E–08	2.0E–02
LBL	5,856,829 174	1.8E–02	2.9E–07	5.1E–02	6.2E–02	9.7E–07	2.7E–02
LANL	159,152 902	2.1E–04	2.2E–08	3.3E–01	7.1E–04	7.5E–08	4.9E–01
ORNL	881,652 4,281	3.0E–01	9.3E–06	8.5E–01	1.0	3.2E–05	1.5
SNL-NM	610,714 210	1.8E–06	7.2E–11	5.1E–02	6.2E–06	2.4E–10	1.5E–03
SRS	620,618 2,598	6.1E–04	5.7E–09	8.3E–01	2.1E–03	2.0E–08	9.6E–01
ANL-E	7,939,785 224	2.5E–06	1.4E–11	8.3E–02	8.5E–06	4.7E–11	1.1E–01
KCP	1,729,833 11	1.1E–09	4.8E–14	2.6E–03	3.6E–09	1.6E–13	1.0E–04
LLNL	6,324,234 227	4.4E–03	7.1E–08	5.9E–02	1.5E–02	2.4E–07	8.9E–03
Mound	3,032,983 435	1.0E–07	5.9E–12	1.1E–01	3.5E–07	2.0E–11	4.7E–03
NTS	14,266 108	1.6E–12	4.1E–16	1.3E–02	5.5E–12	1.4E–15	1.0E–03
K-25	871,406 1,040	6.1E–08	1.3E–12	8.9E–02	2.1E–07	4.5E–12	1.9E–02
Y-12	895,379 498	1.4E–08	5.1E–13	5.4E–02	4.7E–08	1.7E–12	7.1E–03
PGDP	500,502 497	2.1E–08	2.4E–12	1.1E–01	7.2E–08	8.0E–12	5.2E–03
Pantex	265,185 214	4.4E–07	3.7E–11	2.6E–02	1.5E–06	1.3E–10	2.7E–03
Pinellas	2,532,174 21	1.8E–08	3.8E–13	5.1E–03	6.0E–08	1.3E–12	2.0E–04
PORTS	639,602 1,087	1.8E–09	2.2E–13	2.4E–01	5.9E–09	7.5E–13	1.6E–02

Table D.3.2–31. Programwide Risks Associated With Treatment of LLW Under Regionalized Alternative 5, by Site—Continued

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.1E-10	1.4E-01
WVDP	1,698,391 463	2.1E-06	3.1E-11	6.6E-02	7.2E-06	1.1E-10	4.5E-10
Total		3.7E-01	9.3E-06	5.1	1.2	3.2E-05	5.9

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–32. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 9,856	7.5E-02	1.5E-06	3.7	2.5E-01	5.2E-06	5.3
KAPL-K	1,290,172 650	5.3E-04	1.2E-08	1.5E-01	1.8E-03	4.0E-08	2.0E-02
LBL	5,856,829 174	1.8E-02	2.9E-07	5.1E-02	6.2E-02	9.7E-07	2.7E-02
LANL	159,152 902	2.1E-04	2.2E-08	3.3E-01	7.1E-04	7.5E-08	4.9E-01
SNL-NM	610,714 210	1.8E-06	7.2E-11	5.1E-02	6.2E-06	2.4E-10	1.5E-03
SRS	620,618 1,986	1.2E-05	1.2E-10	6.6E-01	4.2E-05	3.9E-10	7.9E-01
INEL	153,061 677	8.0E-07	9.9E-11	3.2E-01	2.7E-06	3.4E-10	5.8E-01
ORNL	881,652 382	1.2E-05	3.5E-10	1.2E-01	3.9E-05	1.2E-09	2.5E-01
KCP	1,729,833 11	1.1E-09	4.8E-14	2.6E-03	3.6E-09	1.6E-13	1.0E-04
ANL-E	7,939,785 224	2.5E-06	1.4E-11	8.3E-02	8.5E-06	4.7E-11	1.1E-01
LLNL	6,324,234 227	4.4E-03	7.1E-08	5.9E-02	1.5E-02	2.4E-07	8.9E-03
Mound	3,032,983 435	1.0E-07	5.9E-12	1.1E-01	3.5E-07	2.0E-11	4.7E-03
K-25	871,406 1,259	3.2E-07	7.0E-12	1.2E-01	1.1E-06	2.4E-11	1.9E-02
Y-12	895,379 618	4.0E-08	1.5E-12	6.7E-02	1.4E-07	5.0E-12	7.1E-03
PGDP	500,502 497	2.1E-08	2.4E-12	1.1E-01	7.2E-08	8.0E-12	5.2E-03
Pantex	265,185 214	4.4E-07	3.7E-11	2.6E-02	1.5E-06	1.3E-10	2.7E-03
Pinellas	2,532,174 21	1.8E-08	3.8E-13	5.1E-03	6.0E-08	1.3E-12	2.0E-04
PORTS	639,602 1,087	1.8E-09	2.2E-13	2.4E-01	5.9E-09	7.5E-13	1.6E-02

Table D.3.2-32. Programwide Risks Associated With Treatment of LLW Under Centralized Alternative 5, by Site—Continued

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
RFETS	2,171,877 344	4.0E-07	5.4E-12	8.1E-02	1.4E-06	1.8E-11	4.0E-03
BNL	5,738,554 417	2.3E-06	3.1E-11	8.3E-02	7.9E-06	1.1E-10	1.4E-01
WVDP	1,698,391 463	2.1E-06	3.1E-11	6.6E-02	7.2E-06	1.1E-10	4.5E-02
NTS	14,266 108	1.6E-12	4.1E-16	1.3E-02	5.5E-12	1.4E-15	1.0E-03
Total		9.8E-02	1.5E-06	6.4	3.3E-01	5.2E-06	7.8

[a] Top number represents the offsite population within an 80-km of the site, while the bottom number represents the total FTEs for WM workers involved in construction and operation activities.
[b] Includes worker fatalities associated with radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–33. Programwide Risks Associated With Disposal of LLW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)		
	Cancer fatalities	1.2E+01	
	Cancer incidence	5.7E–03	
	Genetic effects	2.0E–02	
	Hazard index	1.2E–03	
All lifetimes	Dose (person-rem)		
	Cancer fatalities	1.5E+02	
	Cancer incidence	7.6E–02	
	Genetic effects	2.6E–01	
	Hazard index	1.5E–02	
WM workers	Dose (FTE-rem)	8.0E+03	
	Cancer fatalities	3.2	
	Cancer incidence	1.1E+01	
	Genetic effects	4.9E–01	
	Exposure index		
	Construction fatalities		1.6
	Construction injuries		7.0E+02
	Operation fatalities		1.8
	Operation injuries		1.4E+02

Table D.3.2–34. Programwide Risks Associated With Disposal of LLW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	1.3E+02	
	Cancer fatalities	6.7E–02	
	Cancer incidence	2.3E–01	
	Genetic effects	1.3E–02	
	Hazard index		
All lifetimes	Dose (person-rem)	2.6E+03	
	Cancer fatalities	1.3	
	Cancer incidence	4.5	
	Genetic effects	2.6E–01	
	Hazard index		
WM workers	Dose (FTE-rem)	6.5E+03	
	Cancer fatalities	2.6	
	Cancer incidence	9.0	
	Genetic effects	3.9E–01	
	Exposure index		
	Construction fatalities		3.9
	Construction injuries		1.6E+03
	Operation fatalities		1.6
	Operation injuries		1.3E+03

Table D.3.2–35. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	3.0	
	Cancer fatalities	1.5E–03	
	Cancer incidence	5.1E–03	
	Genetic effects	3.0E–04	
	Hazard index		
All lifetimes	Dose (person-rem)	4.4E+01	
	Cancer fatalities	2.2E–02	
	Cancer incidence	7.4E–02	
	Genetic effects	4.4E–03	
	Hazard index		
WM workers	Dose (FTE-rem)	6.1E+03	
	Cancer fatalities	2.5	
	Cancer incidence	8.6	
	Genetic effects	3.6	
	Exposure index		
	Construction fatalities		3.8
	Construction injuries		1.6E+03
	Operation fatalities		1.6
	Operation injuries		1.3E+03

Table D.3.2–36. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	2.3	
	Cancer fatalities	1.1E–03	
	Cancer incidence	3.9E–03	
	Genetic effects	2.3E–04	
	Hazard index		
All lifetimes	Dose (person-rem)	3.1E+01	
	Cancer fatalities	1.6E–02	
	Cancer incidence	5.3E–02	
	Genetic effects	3.1E–03	
	Hazard index		
WM workers	Dose (FTE-rem)	6.9E+03	
	Cancer fatalities	2.8	
	Cancer incidence	9.6	
	Genetic effects	4.1E–01	
	Exposure index		
	Construction fatalities		3.5
	Construction injuries		1.5E+03
	Operation fatalities		1.4
	Operation injuries		1.0E+03

Table D.3.2–37. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 6, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	3.3E+01	
	Cancer fatalities	1.6E–02	
	Cancer incidence	5.6E–02	
	Genetic effects	3.3E–03	
	Hazard index		
All lifetimes	Dose (person-rem)	4.3E+02	
	Cancer fatalities	2.2E–01	
	Cancer incidence	7.3E–01	
	Genetic effects	4.3E–02	
	Hazard index		
WM workers	Dose (FTE-rem)	4.4E+03	
	Cancer fatalities	1.8	
	Cancer incidence	6.2	
	Genetic effects	2.6E–01	
	Exposure index		
	Construction fatalities		5.1
	Construction injuries		2.2E+03
	Operation fatalities		1.3
	Operation injuries		1.1E+03

Table D.3.2–38. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 7, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	3.4E–01	
	Cancer fatalities	1.7E–04	
	Cancer incidence	5.9E–04	
	Genetic effects	3.4E–05	
	Hazard index		
All lifetimes	Dose (person-rem)	3.7	
	Cancer fatalities	1.8E–03	
	Cancer incidence	6.3E–03	
	Genetic effects	3.7E–04	
	Hazard index		
WM workers	Dose (FTE-rem)	3.5E+03	
	Cancer fatalities	1.4	
	Cancer incidence	4.9	
	Genetic effects	2.1E–01	
	Exposure index		
	Construction fatalities		4.9
	Construction injuries		2.2E+03
	Operation fatalities		1.1
	Operation injuries		7.8E+02

Table D.3.2–39. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	9.6	
	Cancer fatalities	4.8E–03	
	Cancer incidence	1.6E–02	
	Genetic effects	9.6E–04	
	Hazard index		
All lifetimes	Dose (person-rem)	1.3E+02	
	Cancer fatalities	6.4E–02	
	Cancer incidence	2.2E–01	
	Genetic effects	1.3E–02	
	Hazard index		
WM workers	Dose (FTE-rem)	6.9E+03	
	Cancer fatalities	2.8	
	Cancer incidence	9.7	
	Genetic effects	4.2E–01	
	Exposure index		
	Construction fatalities		4.0E–01
	Construction injuries		1.7E+02
	Operation fatalities		9.6E–01
	Operation injuries		8.1E+02

Table D.3.2–40. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	0.0	
	Cancer fatalities	0.0	
	Cancer incidence	0.0	
	Genetic effects	0.0	
	Hazard index		
All lifetimes	Dose (person-rem)	0.0	
	Cancer fatalities	0.0	
	Cancer incidence	0.0	
	Genetic effects	0.0	
	Hazard index		
WM workers	Dose (FTE-rem)	5.5E+03	
	Cancer fatalities	2.2	
	Cancer incidence	7.7	
	Genetic effects	3.3E–01	
	Exposure index		
	Construction fatalities		1.7E–01
	Construction injuries		4.7E–01
	Operation fatalities		4.4E–01
	Operation injuries		1.1E+02

Table D.3.2–41. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	1.0E+01	
	Cancer fatalities	5.2E-03	
	Cancer incidence	1.8E-02	
	Genetic effects	1.0E-03	
	Hazard index		
All lifetimes	Dose (person-rem)	1.5E+02	
	Cancer fatalities	7.2E-02	
	Cancer incidence	2.5E-01	
	Genetic effects	1.5E-02	
	Hazard index		
WM workers	Dose (FTE-rem)	4.9E+03	
	Cancer fatalities	2.0	
	Cancer incidence	6.9	
	Genetic effects	3.0E-01	
	Exposure index		
	Construction fatalities		3.0
	Construction injuries		1.3E+03
	Operation fatalities		1.1
	Operation injuries		9.1E+02

Table D.3.2–42. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	2.7E+01	
	Cancer fatalities	1.4E-02	
	Cancer incidence	4.7E-02	
	Genetic effects	2.7E-03	
	Hazard index		
All lifetimes	Dose (person-rem)	3.6E+02	
	Cancer fatalities	1.9E-01	
	Cancer incidence	6.2E-01	
	Genetic effects	3.6E-02	
	Hazard index		
WM workers	Dose (FTE-rem)	5.3E+03	
	Cancer fatalities	2.1	
	Cancer incidence	7.4	
	Genetic effects	3.2E-01	
	Exposure index		
	Construction fatalities		2.8
	Construction injuries		1.2E+03
	Operation fatalities		9.8E-01
	Operation injuries		7.4E+02

Table D.3.2-43. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	1.8E+01	
	Cancer fatalities	9.2E-03	
	Cancer incidence	3.1E-02	
	Genetic effects	1.8E-03	
	Hazard index		
All lifetimes	Dose (person-rem)	2.5E+02	
	Cancer fatalities	1.2E-01	
	Cancer incidence	4.2E-01	
	Genetic effects	2.5E-02	
	Hazard index		
WM workers	Dose (FTE-rem)	4.4E+03	
	Cancer fatalities	1.8	
	Cancer incidence	6.2	
	Genetic effects	2.7E-01	
	Exposure index		
	Construction fatalities		2.5E-01
	Construction injuries		1.1E+02
	Operation fatalities		6.3E-01
	Operation injuries		5.4E+02

Table D.3.2-44. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	0.0	
	Cancer fatalities	0.0	
	Cancer incidence	0.0	
	Genetic effects	0.0	
	Hazard index		
All lifetimes	Dose (person-rem)	0.0	
	Cancer fatalities	0.0	
	Cancer incidence	0.0	
	Genetic effects	0.0	
	Hazard index		
WM workers	Dose (FTE-rem)	3.9E+03	
	Cancer fatalities	1.6	
	Cancer incidence	5.5	
	Genetic effects	2.3E-01	
	Exposure index		
	Construction fatalities		1.0E-01
	Construction injuries		2.9E+01
	Operation fatalities		2.9E-01
	Operation injuries		7.4E+01

Table D.3.2–45. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	2.7E+01	
	Cancer fatalities	1.4E-02	
	Cancer incidence	4.7E-02	
	Genetic effects	2.7E-03	
	Hazard index		
All lifetimes	Dose (person-rem)	3.6E+02	
	Cancer fatalities	1.8E-01	
	Cancer incidence	6.3E-01	
	Genetic effects	3.6E-02	
	Hazard index		
WM workers	Dose (FTE-rem)	5.3E+03	
	Cancer fatalities	2.1	
	Cancer incidence	7.4	
	Genetic effects	3.2E-01	
	Exposure index		
	Construction fatalities		2.8
	Construction injuries		1.2E+03
	Operation fatalities		9.8E-01
	Operation injuries		7.5E+02

Table D.3.2–46. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 5, by Health Endpoint

Receptor	Endpoint	Radionuclides	Physical Hazards
Maximally exposed farm family	Dose (person-rem)	1.8E+01	
	Cancer fatalities	9.2E-03	
	Cancer incidence	3.1E-02	
	Genetic effects	1.8E-03	
	Hazard index		
All lifetimes	Dose (person-rem)	2.5E+02	
	Cancer fatalities	1.2E-01	
	Cancer incidence	4.2E-01	
	Genetic effects	2.5E-02	
	Hazard index		
WM workers	Dose (FTE-rem)	4.4E+03	
	Cancer fatalities	1.8	
	Cancer incidence	6.2	
	Genetic effects	2.6E-01	
	Exposure index		
	Construction fatalities		2.5E-01
	Construction injuries		1.1E+02
	Operation fatalities		6.3E-01
	Operation injuries		5.3E+02

Table D.3.2-47. Programwide Risks Associated With Disposal of LLW Under the No Action Alternative, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
LANL (0)	0.00	0.00	1.2	0.00	0.00	2.9
NTS (0)	0.00	0.00	2.1E-01	0.00	0.00	5.7E-02
SRS (153)	1.5E-04	2.2E-03	2.8	5.0E-04	7.3E-03	2.5
ORR (22)	8.9E-07	1.3E-05	4.9E-01	3.0E-06	4.4E-06	1.2
Hanford (18)	5.6E-03	8.0E-02	1.1	1.9E-02	2.7E-01	2.3
INEL (0)	0.00	0.00	8.5E-01	0.00	0.00	2.2
Total	5.7E-03	7.6E-02	6.6	2.0E-02	2.6E-01	1.1E+01

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-48. Programwide Risks Associated With Disposal of LLW Under the Decentralized Alternative, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	6.6E-01	0.00	0.00	1.5
LLNL (142)	4.4E-06	6.8E-05	2.3E-01	1.5E-05	2.3E-04	5.6E-01
LANL (0)	0.00	0.00	8.8E-01	0.00	0.00	2.0
ORR (22)	7.3E-07	1.1E-05	5.4E-01	2.5E-06	3.6E-05	1.1
SNL-NM (15)	6.3E-02	1.1	9.5E-02	2.1E-01	3.9	2.2E-01
PGDP (42)	3.7E-04	6.1E-03	1.5E-01	1.3E-03	2.1E-02	1.1E-02
Pantex (0)	0.00	0.00	2.1E-02	0.00	0.00	2.0E-03
RFETS (38)	1.1E-07	2.1E-06	1.4E-01	3.7E-07	7.0E-06	9.9E-03
SRS (153)	1.1E-04	1.7E-03	4.1	3.8E-04	5.6E-03	2.0
PORTS (37)	2.4E-07	4.5E-06	4.4E-01	8.2E-07	1.5E-05	4.6E-02
ANL-E (64)	1.1E-04	5.1E-03	1.1E-01	3.9E-04	1.7E-02	1.5E-01
Hanford (18)	1.0E-03	1.4E-02	5.6E-01	3.4E-03	4.7E-02	1.3
NTS (0)	0.00	0.00	1.4E-02	0.00	0.00	1.5E-03
WVDP (90)	5.3E-04	3.8E-02	9.3E-02	1.8E-03	1.3E-01	8.7E-02
BNL (78)	1.8E-03	1.1E-01	6.0E-02	6.3E-03	3.8E-01	1.3E-01
Total	6.5E-02	1.2	8.0	2.2E-01	4.1	9.0

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-49. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 1, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.0E-03	1.4E-02	5.6E-01	3.4E-03	4.7E-02	1.3
INEL (0)	0.00	0.00	6.6E-01	0.00	0.00	1.5
LLNL (142)	4.4E-06	6.8E-05	2.3E-01	1.5E-05	2.3E-04	5.6E-01
LANL (0)	0.00	0.00	8.9E-01	0.00	0.00	2.0
ORR (22)	7.3E-07	1.1E-05	5.4E-01	2.5E-06	3.6E-05	1.1
PORTS (145)	2.0E-06	7.7E-05	5.2E-01	6.9E-06	2.6E-04	1.1E-01
PGDP (42)	3.7E-04	6.1E-03	1.5E-01	1.3E-03	2.1E-02	1.1E-02
Pantex (0)	5.8E-10	4.9E-09	3.9E-03	2.0E-09	1.7E-08	6.6E-04
SRS (153)	1.2E-04	1.8E-03	4.1	4.1E-04	6.0E-03	2.0
RFETS (38)	1.1E-07	2.1E-06	1.4E-01	3.7E-07	7.0E-06	9.9E-03
NTS (0)	0.0	0.0	1.4E-02	0.0	0.0	1.5E-03
Total	1.5E-03	2.2E-02	7.8	5.1E-03	7.4E-02	8.6

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-50. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 3, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.0E-03	1.4E-02	5.6E-01	3.4E-03	4.7E-02	1.3
INEL (0)	0.00	0.00	6.6E-01	0.00	0.00	1.5
LANL (0)	0.00	0.00	1.2	0.00	0.00	2.7
NTS (0)	0.00	0.00	8.0E-02	0.00	0.00	1.3E-01
ORR (22)	5.0E-07	7.2E-06	9.5E-01	1.7E-06	2.5E-05	1.9E+00
SRS (153)	1.2E-04	1.8E-03	4.1	4.1E-04	6.0E-03	2.0
Total	1.1E-03	1.6E-02	7.6	3.9E-03	5.3E-02	9.6

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–51. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 6, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.6E-02	2.2E-01	1.8	5.5E-02	7.3E-01	4.0
SRS (23)	1.7E-04	1.9E-03	6.4	5.9E-04	6.6E-03	2.1
Total	1.6E-02	2.2E-01	8.2	5.6E-02	7.4E-01	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–52. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 7, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	1.1	0.00	0.00	2.8
SRS (23)	1.7E-04	1.9E-03	6.4	5.9E-04	6.3E-03	2.1
Total	1.7E-04	1.9E-03	7.5	5.9E-04	6.3E-03	4.9

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–53. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 1, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	4.8E-03	6.4E-02	4.1	1.6E-02	2.2E-01	9.7
Total	4.8E-03	6.4E-02	4.1	1.6E-02	2.2E-01	9.7

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-54. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 2, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	2.8	0.00	0.00	7.7
Total	0.00	0.00	2.8	0.00	0.00	7.7

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-55. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 2, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	4.5E-03	6.2E-02	4.3E-01	1.5E-02	2.1E-01	1.1
INEL (0)	0.00	0.00	4.9E-01	0.00	0.00	1.2
LLNL (142)	4.4E-06	6.8E-05	1.9E-01	1.5E-05	2.3E-04	4.7E-01
LANL (0)	0.00	0.00	5.3E-01	0.00	0.00	1.3
ORR (22)	1.6E-06	2.3E-05	3.5E-01	5.3E-06	7.7E-05	7.4E-01
PORTS (145)	3.5E-06	1.3E-04	3.2E-01	1.2E-05	4.5E-04	9.3E-02
PGDP (42)	5.0E-04	8.1E-03	1.3E-01	1.7E-03	2.8E-02	9.7E-03
Pantex (0)	0.00	0.00	2.1E-02	0.00	0.00	2.0E-03
SRS (153)	1.4E-04	2.1E-03	3.5	4.9E-04	7.2E-03	2.0
RFETS (38)	3.2E-07	6.2E-06	6.8E-02	1.1E-06	2.1E-05	5.6E-03
NTS (0)	0.0	0.0	3.8E-03	0.0	0.0	4.0E-04
Total	5.2E-03	7.2E-02	6.1	1.8E-02	2.5E-01	6.9

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–56. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 4, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
LANL (0	0.00	0.00	5.7E–01	0.00	0.00	1.4
ORR (22)	7.4E–07	1.1E–05	7.7E–01	2.5E–06	3.6E–05	1.7
NTS (0)	0.00	0.00	2.2E–02	0.00	0.00	2.7E–02
SRS (153)	1.4E–04	2.1E–03	3.5	4.9E–04	7.2E–03	2.0
INEL (0)	0.00	0.00	5.2E–01	0.00	0.00	1.3
Hanford (18)	1.4E–02	1.8E–01	4.3E–01	4.6E–02	6.1E–01	1.1
Total	1.4E–02	1.9E–01	5.9	4.7E–02	6.2E–01	7.5

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–57. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 3, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.2E–03	1.2E–01	2.7	3.1E–02	4.2E–01	6.2
Total	9.2E–03	1.2E–01	2.7	3.1E–02	4.2E–01	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–58. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 4, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	2.0	0.00	0.00	5.5
Total	0.00	0.00	2.0	0.00	0.00	5.5

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2–59. Programwide Risks Associated With Disposal of LLW Under Regionalized Alternative 5, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.4E–02	1.8E–01	4.3E–01	4.6E–02	6.1E–01	1.1
LANL (0)	0.00	0.00	5.9E–01	0.00	0.00	1.4
ORR (22)	7.4E–07	1.1E–05	7.7E–01	2.5E–06	3.6E–05	1.7
NTS (0)	0.00	0.00	2.2E–02	0.00	0.00	2.7E–02
SRS (153)	1.4E–04	2.1E–03	3.5	4.9E–04	7.2E–03	2.0
INEL (0)	0.00	0.00	4.9E–01	0.00	0.00	1.2
Total	1.4E–02	1.8E–01	5.9	4.7E–02	6.2E–01	7.5

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

Table D.3.2-60. Programwide Risks Associated With Disposal of LLW Under Centralized Alternative 5, by Site

Site (Lifetime)	Fatalities[a]			Cancer Incidence[b]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.2E-03	1.2E-01	2.6	3.1E-02	4.2E-01	6.2
Total	9.2E-03	1.2E-01	2.6	3.1E-02	4.2E-01	6.2

[a] Includes cancer fatalities associated with radiation exposure for farm family and fatality associated with radiation exposure and physical hazards for workers.
[b] Indicates cancer incidence associated with radiation exposure.

D.3.2.4 Results of the LLW Human Health Risk Analysis for Routine Operations

D.3.2.4.1 *Programwide Trends in Human Health Risks Associated With LLW Management Alternatives*

In general, No Action presents the lowest health risks for all public populations and for all health risk endpoints. For the offsite population the risks of cancer fatality due to the treatment of LLW are within 2.5 orders of magnitude for all alternatives (2.0E–03 to 6.4E–01). Risks to the noninvolved worker population and to MEIs follow the same general trend. Regionalized Alternative 2 (regionalized volume reduction at 11 installations) produces the highest risk of cancer fatalities, though it is still within an order of magnitude of all the other alternatives. The health risks tend to increase as the level of treatment increases and where a treatment installation is situated in a highly populated area.

Overall, estimated worker health risks associated with management of LLW are similar among alternatives; however, the highest worker risks tend to be for installations with waste consolidation (i.e., larger waste loads) for treatment and for installations with more treatment facility construction.

Estimated impacts to each of the receptor populations are presented below.

Offsite Population. The lowest risks of cancer fatality to the offsite population are from the No Action Alternative (2.0E–03), the Decentralized Alternative, Regionalized Alternatives 1, 3, 6, 7, and Centralized Alternatives 1 and 2. All are in the E–02 order of magnitude and affect a total population of 44 million people. Except for the No Action Alternative, all of these installations perform minimum treatment (although some volume reduction is performed in the No Action Alternative); the only variation is in the various disposal configurations. The risks of cancer fatality associated with Regionalized Alternatives 4 and 5 and Centralized Alternatives 3, 4, and 5 are similar to one another (ranging from 9.7E–02 to 3.7E–01 over a total affected population of approximately 44 million) and are about 0.5 to 2 orders of magnitude higher than for the other alternatives.

Regionalized 2 poses the highest risks to the offsite population by approximately 0.5 orders of magnitude (an estimated 6.4E–01 cancer fatalities over 47 million people). This is because the largest combined population (11 sites totaling about 14.8 million people) is affected by volume reduction (which includes

incineration). The highest installation-specific risks are associated with LLNL (an estimated 3.9E–01 cancer fatalities over a population of approximately 6.3 million); the radionuclide contributing the most risk is tritium, via inhalation and ingestion. The lowest risks to an offsite population at a particular installation are at NTS for all alternatives.

Inspection of Table D.3.2–6 shows that for all alternatives in which incineration is the major volume-reduction treatment (Regionalized 2, 4, and 5, and Centralized 3, 4, and 5), cancer fatality risks in the E–01 order of magnitude are attributable to tritium except in Regionalized 4, and Centralized 3 and 4. In these three alternatives, both tritium and uranium–238 contribute cancer fatality risks on the order of E–01.

Noninvolved Worker Population. The trends in programwide health risks to the noninvolved worker population are similar to those observed for the offsite population; both the programwide risks and the total affected population are lower by approximately 2 orders of magnitude.

The estimated risk of cancer fatality to the noninvolved worker population in Regionalized 2 (6.6E–03 cancer fatalities in a population of 126,415) are about three to six times higher than in the other volume reduction alternatives. The smallest risk of cancer fatality (6.0E–05) occurs in the No Action Alternative.

The risks in the Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives are identical to one another (1.9E–04) because the treatment is the same at all sites. The risks to the noninvolved worker population are 1 to 1.5 orders of magnitude higher in Regionalized 4, and 5 and Centralized 3, 4, and 5 than in the minimum treatment alternatives.

Maximally Exposed Noninvolved Workers and Maximally Exposed Offsite Individuals. Radiological exposure risks to the noninvolved worker and offsite MEIs are lowest in the No Action Alternative; the Decentralized, Regionalized 1, 3, 6, 7, and Centralized 1 and 2 Alternatives are higher by 2 to 3 orders of magnitude. Another order of magnitude higher occurs in Regionalized 4 and Centralized 3, 4, and 5. The highest radiological exposure risks to the noninvolved worker and offsite MEIs occur in Regionalized 2 and 5.

The programwide risk of cancer incidence for both MEIs is in the E–05 to E–07 range in Regionalized 2, 4, and 5 and Centralized 3, 4, and 5 (see Table D.3.2–5). Across the program, the highest risk of cancer fatality for both MEIs is in Regionalized 5 (an estimated risk of 9.3E–06 for the offsite MEI and 4.1E–06

for the noninvolved worker MEI). At the installation level, the highest risks of cancer fatality to the offsite MEI are at FEMP (4.4E-06) and LLNL (6.3E-06) in Regionalized 2; PORTS (2.3E-06) in Regionalized 4; Hanford (1.0E-06) and PORTS (2.3E-06) in Centralized 3 and 4; ORNL (9.3E-06) in Regionalized 5; and Hanford (1.5E-06) in Centralized 5. These elevated risks are the result of volume reduction (including incineration) of relatively large volumes of volatile waste containing tritium. All cancer fatality risks to both MEIs for minimum treatment alternatives are below E-06.

Workers. The programwide estimated risks of cancer fatality to workers vary by no more than a factor of three across all alternatives. The risks for the minimum treatment alternatives (Decentralized, Regionalized 1, 3, 6, and 7 and Centralized 1 and 2) are nearly identical to one another (approximately 8.3E-01 cancer fatalities across 10,191 to 12,077 FTEs), and are slightly higher in the No Action Alternative and volume reduction alternatives Regionalized 2, 4, and 5, and Centralized 3 and 4). The highest programwide cancer fatality risk is incurred in Centralized Alternative 5 (2.3 over a total population of 20,762 FTEs), in which all waste is treated by volume reduction at Hanford.

Estimated construction fatality risks for workers are lowest in the No Action Alternative (8.2E-01), in which no new treatment facilities are to be built. New facilities will be required at several installations in the volume reduction alternatives (Regionalized 2, 4, and 5, and Centralized 3, 4, and 5); however, the risks in these alternatives are higher than in the remaining alternatives by only a factor of two. Estimated operational fatalities are slightly higher (by about a factor of two or less) for the No Action Alternative (1.7) and the volume reduction alternatives (1.8 to 2.1) than for the minimum treatment alternatives (1.0 to 1.1). This is because more worker person-hours are required for the 20-year No Action treatment period and for the more extensive treatment in the volume reduction alternatives.

Although worker risks are very similar across alternatives, some differences in installation risks are notable. The estimated total fatalities (cancer fatalities plus construction and operational fatalities) in the No Action and minimum treatment alternatives are consistently very similar among installations (E-02 to E-01 range) except at KCP, NTS, and Pinellas (E-03 order of magnitude), which have much smaller waste loads to treat and employ fewer workers (11 to 13, 21 to 26, 64 to 108 FTES, respectively) than are needed at other installations.

By a slight margin, LANL and SRS pose the highest total worker fatality risks in the Regionalized 2, 4, and 5, and Centralized 3 and 4 volume reduction alternatives (total fatalities range from 8.3E-01 to

9.3E-01); however, the risks among installations in these alternatives are within approximately 1 order of magnitude except at KCP and Pinellas, at which worker fatality risks are 1 to 2 orders of magnitude lower in all alternatives. The slight elevation in risks at LANL and SRS in the volume-reduction alternatives reflects consolidation of waste loads at these installations for treatment, additional construction of treatment facilities, and the presence of a large number of FTEs at ORNL in these scenarios. Total fatalities also increase slightly at INEL (1.34) in Regionalized Alternative 5, in which volume reduction is performed at four installations; this is due mainly to larger consolidated waste loads in treatment and a larger exposed work force than for other alternatives. The highest estimated total fatalities are in Centralized Alternative 5 at Hanford (3.65 in 9,856 FTEs), where all volume reduction is performed and the treatment work force is greatly increased compared to other alternatives.

D.3.2.4.2 *Programwide Trends in Human Health Risks Associated With LLW Disposal*

For the MEL of the hypothetical farm family, the health risks associated with the LLW disposal alternatives show no discernable trends. The risk of cancer fatality to all 143 farm family lifetimes across alternatives ranges from 0.0 to 1.3 cancer fatalities over 10,000 years. Estimated cancer fatalities for workers during disposal are very similar across alternatives, ranging from 1.4 to 3.2; worker risks tend to increase as the waste load to be disposed of becomes larger and as more disposal facility construction is required.

Maximally Exposed Lifetime of the Hypothetical Farm Family. For each alternative, with the exception of Centralized Alternatives 2 and 4 (single site disposal at NTS), the risk of cancer incidence to the MEL of the farm family is greater than 1E-04. For the "average" individual member of the farm family, the risk of cancer incidence (determined by dividing the cancer incidence risk in Table D.3.2-3 by the number of family members, four, times the number of disposal sites for that alternative), may be considered above the target exposure level in all alternatives except Centralized 2 and 4.

The highest cancer fatality risks to the MEL are in Decentralized (in which wastes receive minimum treatment and are then disposed of at 12 installations). Estimated programwide cancer fatality risks are 6.5E-02 in Decentralized.

The lowest risks of cancer fatality to the MEL are in Centralized 2 (minimum treatment and disposal at NTS) and Centralized 4 (volume reduction at seven installations and disposal at NTS). The programwide risks of cancer fatality for the four-member farm family are 0.0 in Centralized 2 and in Centralized 4.

At the installation level, the lowest disposal risks are at LANL in the No Action, Decentralized, Regionalized 1, 2, 3, 4, and 5 Alternatives; at NTS in the No Action, Regionalized 2, 3, 4, 5, and 7, and Centralized 2 and 4 Alternatives; at Pantex in the Decentralized and Regionalized 2 Alternatives; and at INEL in the No Action, Decentralized, and Regionalized 1, 2, 3, 4, and 5 Alternatives. The estimated radiological risks at these installations are zero because the wastes being disposed of contain low concentrations of radionuclides and the migration of the contaminants into the groundwater is very slow (all four installations receive little annual rainfall).

The highest "average" disposal installation risk to a farm family member is at SNL-NM in the Decentralized Alternative (average individual risk of cancer fatality is 6.3E–02). The MEL is lifetime 15 at SNL-NM, where uranium-238 contributes over 99% of the dose received by farm family members.

Workers Placing Wastes Into Disposal. The estimated worker risks from disposal are very similar across alternatives, ranging from 1.4 to 3.2 for cancer fatality and 4.9 to 11 for cancer incidence. However, the estimated risk of fatality from construction is more than 1 order of magnitude lower for the one-installation disposal alternatives (the five Centralized Alternatives) than for the other alternatives. In the Centralized scenarios, Hanford and NTS are the single-disposal installations; both have large amounts of existing disposal capacity compared to other installations and, therefore, require less new construction.

The highest construction fatality risks occur in Regionalized 6 and 7; these alternatives involve two-installation disposal at Hanford and SRS and NTS and SRS, respectively. The majority of the construction-related worker risks are at SRS, which has a relatively small amount of existing disposal capacity and, based on the large amount of LLW to be sent there for disposal in these disposal scenarios, would require extensive construction.

The estimated number of operational fatalities is within 1 order of magnitude among alternatives (ranging from 2.9E–01 to 1.8). In general, operational fatalities are slightly higher for scenarios in which multiple installations dispose (the No Action, Decentralized, and Regionalized 1 and 3 Alternatives), and are slightly lower where only one installation disposes (the Centralized Alternatives). This is because the fewer the

disposal installations, the fewer the number of FTEs needed to operate them (therefore, fewer workers are around to be involved in operational accidents).

Although overall risks to workers from disposal do not differ appreciably among alternatives, some trends are apparent in the installation-specific risks associated with disposal. In the multiple-installation disposal alternatives (the No Action, Decentralized, and Regionalized Alternatives), the same four installations, Hanford, INEL, SRS, and LANL, have the highest cancer risks by approximately 0.5 to 2 orders of magnitude; all four are consolidation installations for LLW disposal in these alternatives. The controlling contaminants are cobalt-60 at Hanford, INEL, and SRS, and cesium–137 and daughter products at LANL; external radiation is the predominant exposure route. In the two-installation disposal alternatives (Hanford and SRS in Regionalized 6; NTS and SRS in Regionalized 7), Hanford and NTS cancer risks are approximately twice as high as those for disposal at SRS. The controlling contaminant for disposal at Hanford and NTS in Regionalized 6 and 7 is cobalt-60; the primary exposure route is external radiation. However, there are more estimated fatalities at SRS due to physical hazards because of the construction of new disposal facilities.

D.3.2.4.3 *Comparison Among Treatment Options*

For workers, comparison of minimum treatment and volume reduction scenarios shows very little difference in cancer risks associated with LLW treatment. In all alternatives, estimated worker cancer fatality risks from treatment are very similar, ranging between 8.1E–01 and 2.3. Overall, worker risks at particular installations seem to be driven primarily by waste consolidation and facility construction.

The programwide risk of cancer fatality for all of the minimum treatment alternatives are identical for all receptors. The overall risks associated with the volume reduction alternatives are approximately 0.5 to 1.5 orders of magnitude higher than the risks associated with minimum treatment only. This can be seen at the installation level as well as at the program level; for example, at RFETS, cancer fatalities in the offsite population increase from 4.0E–07 in Regionalized Alternative 5 (which involves minimum treatment) to 1.9E–04 in Regionalized Alternative 4 (which involves volume reduction). This is attributable to increased atmospheric releases associated with the incineration of LLW.

Comparison of the risks for the volume reduction alternatives shows that the risks for all receptors vary by no more than a factor of six between volume reduction at 11 installations and volume reduction at 7, 4, or 1 installation(s).

D.3.2.4.4 *Comparison Among Disposal Scenarios*

Comparisons can be made between the alternatives in which treatment is the same but the number of disposal sites varies from 12 installations to 1. For the minimum treatment alternatives, the cancer fatality risks to all farm family lifetimes range from 0.0 to 1.2. There are no apparent trends as the number of disposal facilities changes. The cancer fatality risks in the single-installation disposal alternatives (Centralized 1 and 2) are 0.0 at NTS and 4.8E–03 at Hanford.

Comparison of disposal risks among alternatives that have the same disposal scenarios but different treatment options shows that the type of LLW treatment has little effect on the cancer risks to all farm family lifetimes or to the MEL. For example, in the 10-installation disposal alternatives (Regionalized 1 and Regionalized 2), the major difference is that minimum treatment is performed at all installations in Regionalized 1, while additional volume reduction is performed at 11 installations in Regionalized 2. Risks of cancer fatality to all farm family lifetimes from disposal are higher in Regionalized 2 by less than a factor of four. This small difference is found for both the MEL and for all lifetimes across Regionalized 3, 4, and 5 (the six-installation disposal alternatives); Centralized 1, 3, and 5 (the alternatives in which disposal takes place at Hanford); and Centralized 2 and 4 (in which LLW is disposed of at NTS).

As previously noted for worker risks associated with LLW treatment, the disposal risks to workers do not differ appreciably among alternatives; however, certain installation-specific risks tend to be higher where waste loads are consolidated for disposal or where more construction of disposal facilities is required.

D.3.2.4.5 *Summary of Results for Routine Treatment and Disposal of LLW*

Treatment by volume reduction slightly increases the cancer risks to offsite and noninvolved worker populations at a particular installation in comparison to minimum treatment. However, the type of treatment does not affect the subsequent disposal risks to the farm family as much as the amount of waste consolidated

at an installation or the hydrogeology and meteorology of the disposal installation (both of which can markedly affect the migration of contaminants into groundwater). Volume reduction tends to concentrate waste, producing slightly higher estimated risks to the farm family.

In all but two disposal alternatives (Centralized 2 and 4), the programwide risks of cancer incidence to the MEL of the hypothetical farm family exceed 1E–06. Recall that this is a conservative disposal scenario in which the farm family residence and drinking water well are situated 300 m downgradient from the center of a disposal facility, and that the well serves as the sole source of water for the family, their livestock, and crops.

Worker risks are very similar across all alternatives, regardless of treatment type or disposal scenario; programwide risks are within 1 order of magnitude across all treatment alternatives and all disposal alternatives. Fatalities associated with radiation exposure are usually fewer than those due to the physical hazards of constructing and operating treatment and disposal facilities, except in the one-site disposal alternatives at NTS and Hanford. As discussed above, these installations have relatively large existing disposal facility capacities and require less construction. Overall, however, worker risks at specific installations seem to be driven primarily by the amount of waste consolidated for treatment and/or disposal and the amount of facility construction needed.

D.3.2.5 Summary of Alternatives for Potential LLW Accidents

For LLW, health risks from potential incinerator accidents were evaluated for the No Action, Regionalized 2, and Centralized 5 Alternatives (see Section D.3.2.1); no storage-related accidents were analyzed. The types of accidents evaluated were (1) a baghouse area facility fire; (2) an earthquake leading to a fire in the incinerator facility; (3) the crash of a large aircraft (at INEL, SRS, and Hanford) or a small aircraft (at RFETS and PGDP) resulting in fire and explosion; and (4) an incinerator explosion. Accidents in "alpha facilities" (incinerators that process LLW contaminated with alpha-emitting radionuclides) were evaluated for RFETS in Regionalized 2 and for Hanford in Centralized 5.

Aircraft impacts were not evaluated for FEMP, LANL, LLNL, Mound Plant, PGDP, or ORR.

For more detailed information on accident scenarios, see Appendix F.

D.3.2.6 Special Assumptions and Considerations Used in the LLW Accident Analysis

All accident releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops to 99.9%. In the assessment of worker risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intrafacility source term for this accident is, therefore, 1,000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations. During all accidents, one shift of waste management workers is assumed to be inside the facility. Shift size varies from one to eight workers (see Table D.3.2–64), which can be found at the end of Section D.3.2.7.

Incineration accidents are assumed to result in releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.12.1). However, the probability of occurrence is not directly taken into account in the risk calculations. Risks estimates associated with each accident should be interpreted as the consequences if the accident occurred. The incinerator explosion is considered to be "anticipated" (greater than 1.0E–02 per year); the baghouse area fire is considered "unlikely" (1.0E–04 to 1.0E–02 per year); the earthquake with resulting fire is considered "very unlikely" (1.0E–06 to 1.0E–04 per year); and the aircraft impact is regarded as "extremely unlikely" (less than 1.0E–06 per year), (see Appendix F, Table F.2–2). Slightly different labels are assigned to these frequencies in Appendix F.

D.3.2.7 Results Tables for the Risk Analysis of Potential LLW Accidents

Table D.3.2–61 presents a summary of the maximum reasonably foreseeable accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.2–62 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.2–63 through D.3.2–75 present more detailed results by health endpoint and installation.

Table D.3.2-61. Risks From Potential Maximum Reasonably Foreseeable LLW Treatment Facility Accidents, by Alternative and Site

Site	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI		Worker Population	
	CF	CI	CF	CI	CF	CI	CF	CI	CF	CI
No Action										
INEL	5.9E-05	2.0E-04	6.7E-09	2.3E-08	2.2E-05	7.5E-05	1.3E-08	4.5E-08	1.5E-05	5.4E-05
SRS	4.6E-02	1.6E-01	1.4E-06	4.9E-06	9.6E-03	3.3E-02	4.2E-05	1.4E-04	9.5E-03	3.3E-02
Regionalized 2										
FEMP	6.0E-05	2.1E-04	1.6E-08	5.4E-08	2.2E-06	7.6E-06	1.5E-08	5.1E-08	3.6E-07	1.3E-06
Hanford	2.4E-03	8.1E-03	5.5E-08	1.9E-07	1.2E-04	4.2E-04	1.3E-06	4.2E-06	1.0E-05	3.5E-05
INEL	5.9E-05	2.0E-04	6.7E-09	2.3E-08	2.2E-05	7.5E-05	1.3E-08	4.5E-08	1.9E-05	6.7E-05
LANL	8.7E-01	3.0	4.1E-04	1.4E-03	2.5E-01	8.6E-01	7.4E-04	2.5E-03	2.5E-01	8.7E-01
LLNL	2.9	9.8	4.0E-04	1.4E-03	2.1E-01	7.1E-01	3.6E-04	1.2E-03	7.3E-03	2.6E-02
ORR	1.3E-02	4.4E-02	1.1E-06	3.7E-06	8.8E-03	3.0E-02	9.8E-06	3.3E-05	7.8E-04	2.7E-03
PGDP	2.5E-04	8.6E-04	7.4E-08	2.5E-07	4.9E-05	1.7E-04	4.3E-07	1.5E-06	3.8E-05	1.3E-04
PORTS	2.5E-05	8.6E-05	1.7E-08	5.9E-08	1.1E-05	3.8E-05	1.7E-08	5.7E-08	5.2E-06	1.8E-05
RFETS	2.8E-02	9.4E-02	9.8E-07	3.3E-06	4.8E-03	1.6E-02	1.4E-05	4.8E-05	2.1E-03	7.3E-03
SRS	4.6E-02	1.6E-01	1.4E-06	4.9E-06	9.6E-03	3.3E-02	4.2E-05	1.4E-04	1.2E-02	4.1E-02
Centralized 5										
Hanford	4.8	1.6E+01	1.1E-04	3.8E-04	9.1E-01	3.1	9.2E-03	3.1E-02	6.0E-01	2.1

Notes: MEI = maximally exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at an installation. CF = risk of cancer fatality associated with exposure to radionuclides. CI = risk of cancer incidence associated with exposure to radionuclides.

Table D.3.2-62. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential LLW Treatment Accidents, by Site

Site	Offsite Population	Noninvolved Worker Population	WM Worker Population		
			No Action	Regionalized 2	Centralized 5
Hanford	377,645	8,674		1	8
FEMP	2,764,589	2,456		4	
INEL	153,061	8,451	4	5	
LANL	159,152	11,552		6	
LLNL	6,324,234	9,504		1	
ORR	881,652	3,809		6	
PGDP	500,502	1,952		4	
PORTS	639,602	3,226		5	
RFETS	2,171,877	6,993		8	
SRS	620,618	15,996	4	5	

Table D.3.2–63. Accident Risks Associated With LLW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	3.9E-05	4.5E-09	1.0E-05	1.3E-04	1.5E-08	3.6E-05
Incineration, incinerator explosion (A)	2.4E-08	2.7E-12	6.1E-06	8.0E-08	9.1E-12	2.2E-05
Incineration, baghouse area fire (U)	5.9E-07	6.7E-11	1.5E-07	2.0E-06	2.3E-10	5.4E-07
Incineration, large aircraft crash (EU)	5.9E-05	6.7E-09	1.5E-05	2.0E-04	2.3E-08	5.4E-05
Maximum reasonably foreseeable accident	5.9E-05	6.7E-09	1.5E-05	2.0E-04	2.3E-08	5.4E-05

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2–64. Accident Risks Associated With LLW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, large aircraft crash (EU)[b]	4.6E-02	1.4E-06	9.5E-03	1.6E-01	4.9E-06	3.3E-02
Incineration, earthquake (VU)	3.1E-02	9.6E-07	6.3E-03	1.0E-01	3.3E-06	2.2E-02
Incineration, incinerator explosion (A)	1.8E-05	5.8E-10	3.8E-03	6.2E-05	2.0E-09	1.3E-02
Incineration, baghouse area fire (U)	4.6E-04	1.4E-08	9.5E-05	1.6E-03	4.9E-08	3.3E-04
Maximum reasonably foreseeable accident	4.6E-02	1.4E-06	9.5E-03	1.6E-01	4.9E-06	3.3E-02

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-65. Accident Risks Associated With LLW Treatment at FEMP Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	6.0E-05	1.6E-08	3.6E-07	2.1E-04	5.4E-08	1.3E-06
Incineration, incinerator explosion (A)	3.6E-08	9.5E-12	2.1E-07	1.2E-07	3.2E-11	7.5E-07
Incineration, baghouse area fire (U)	9.1E-07	2.4E-10	5.4E-09	3.1E-06	8.1E-10	1.9E-08
Maximum reasonably foreseeable accident	6.0E-05	1.6E-08	3.6E-07	2.1E-04	5.4E-08	1.3E-06

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (< 1E-06).

Table D.3.2-66. Accident Risks Associated With LLW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	1.6E-03	3.7E-08	6.7E-06	5.4E-03	1.3E-07	2.3E-05
Incineration, incinerator explosion (A)	9.5E-07	2.2E-11	4.0E-06	3.2E-06	7.5E-11	1.4E-05
Incineration, baghouse area fire (U)	2.4E-05	5.5E-10	1.0E-07	8.1E-05	1.9E-09	3.5E-07
Incineration, large aircraft crash (EU)	2.4E-03	5.5E-08	1.0E-05	8.1E-03	1.9E-07	3.5E-05
Maximum reasonably foreseeable accident	2.4E-03	5.5E-08	1.0E-05	8.1E-03	1.9E-07	3.5E-05

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (< 1E-06).

Table D.3.2-67. Accident Risks Associated With LLW Treatment at INEL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, large aircraft crash (EU)[b]	5.9E-05	6.7E-09	1.9E-05	2.0E-04	2.3E-08	6.7E-05
Incineration, earthquake (VU)	3.9E-05	4.5E-09	1.3E-05	1.3E-04	1.5E-08	4.5E-05
Incineration, incinerator explosion (A)	2.4E-08	2.7E-12	7.7E-06	8.0E-08	9.1E-12	2.7E-05
Incineration, baghouse area fire (U)	5.9E-07	6.7E-11	1.9E-07	2.0E-06	2.3E-10	6.7E-07
Maximum reasonably foreseeable accident	5.9E-05	6.7E-09	1.9E-05	2.0E-04	2.3E-08	6.7E-05

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-68. Accident Risks Associated With LLW Treatment at LLNL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	2.9	4.0E-04	7.3E-03	9.8	1.4E-03	2.6E-02
Incineration, incinerator explosion (A)	1.7E-03	2.4E-07	4.4E-03	5.9E-03	8.1E-07	1.5E-02
Incineration, baghouse area fire (U)	4.3E-02	6.0E-06	1.1E-04	1.5E-01	2.0E-05	3.8E-04
Maximum reasonably foreseeable accident	2.9	4.0E-04	7.3E-03	9.8	1.4E-03	2.6E-02

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-69. Accident Risks Associated With LLW Treatment at LANL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	8.7E-01	4.1E-04	2.5E-01	3.0	1.4E-03	8.7E-01
Incineration, incinerator (A) explosion	5.2E-04	2.5E-07	1.5E-01	1.8E-03	8.4E-07	5.2E-01
Incineration, baghouse area (U) fire	1.3E-02	6.2E-06	3.7E-03	4.4E-02	2.1E-05	1.3E-02
Maximum reasonably foreseeable accident	8.7E-01	4.1E-04	2.5E-01	3.0	1.4E-03	8.7E-01

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-70. Accident Risks Associated With LLW Treatment at ORR Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	1.8E-02	1.1E-06	7.8E-04	4.4E-02	3.7E-06	2.7E-03
Incineration, incinerator (A) explosion	7.7E-06	6.4E-10	4.7E-04	2.6E-05	2.2E-09	1.6E-03
Incineration, baghouse area (U) fire	1.7E-06	1.4E-10	1.0E-07	5.6E-06	4.7E-10	3.5E-07
Maximum reasonably foreseeable accident	1.3E-02	1.1E-06	7.8E-04	4.4E-02	3.7E-06	2.7E-03

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-71. Accident Risks Associated With LLW Treatment at PGDP Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, earthquake (VU)[b]	2.5E-04	7.4E-08	3.8E-05	8.6E-04	2.5E-07	1.3E-04
Incineration, incinerator explosion (A)	1.5E-07	4.4E-11	2.3E-05	5.2E-07	1.5E-10	7.9E-05
Incineration, baghouse area fire (U)	3.8E-06	1.1E-09	5.6E-07	1.3E-05	3.8E-09	2.0E-06
Incineration, small aircraft crash (EU)	6.3E-05	1.8E-08	9.4E-06	2.2E-04	6.3E-08	3.3E-05
Maximum reasonably foreseeable accident	2.5E-04	7.4E-08	3.8E-05	8.6E-04	2.5E-07	1.3E-04

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (< 1E-06).

Table D.3.2-72. Accident Risks Associated With LLW Treatment at PORTS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, baghouse area fire (U)[b]	3.8E-07	2.6E-10	7.8E-08	1.3E-06	8.8E-10	2.7E-07
Incineration, earthquake (VU)	2.5E-05	1.7E-08	5.2E-06	8.6E-05	5.9E-08	1.8E-05
Incineration, incinerator explosion (A)	1.5E-08	1.0E-11	3.1E-06	5.1E-08	3.5E-11	1.1E-05
Maximum reasonably foreseeable accident	2.5E-05	1.7E-08	5.2E-06	8.6E-05	5.9E-08	1.8E-05

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (< 1E-06).

Table D.3.2-73. Accident Risks Associated With LLW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, small aircraft crash (alpha) (EU)[b]	6.9E-03	2.5E-07	5.2E-04	2.4E-02	8.3E-07	1.8E-03
Incineration, baghouse area fire (alpha) (U)	4.2E-04	1.5E-08	3.1E-05	1.4E-03	5.0E-08	1.1E-04
Incineration, earthquake (alpha) (VU)	2.8E-02	9.8E-07	2.1E-03	9.4E-02	3.3E-06	7.3E-03
Incineration, incinerator explosion (alpha) (A)	1.7E-05	5.9E-10	1.3E-03	5.7E-05	2.0E-09	4.4E-03
Maximum reasonably foreseeable accident	2.8E-02	9.8E-07	2.1E-03	9.4E-02	3.3E-06	7.3E-03

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-74. Accident Risks Associated With LLW Treatment at SRS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[a]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, large aircraft crash (EU)[b]	4.6E-02	1.4E-06	1.2E-02	1.6E-01	4.9E-06	4.1E-02
Incineration, earthquake (VU)	3.1E-02	9.6E-07	7.9E-03	1.0E-01	3.3E-06	2.8E-02
Incineration, incinerator explosion (A)	1.8E-05	5.8E-10	4.7E-03	6.2E-05	2.0E-09	1.7E-02
Incineration, baghouse area fire (U)	4.6E-04	1.4E-08	1.2E-04	1.6E-03	4.9E-08	4.1E-04
Maximum reasonably foreseeable accident	4.6E-02	1.4E-06	1.2E-02	1.6E-01	4.9E-06	4.1E-02

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (<1E-06).

Table D.3.2-75. Accident Risks Associated With LLW Treatment at Hanford Under Centralized Alternative 5, by Accident Type

Accident		Cancer Fatalities[a]			Cancer Incidence[a]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Incineration, large aircraft crash (non-alpha)	(EU)[b]	4.8	1.1E-04	6.0E-01	1.6E+01	3.8E-04	2.1
Incineration, large aircraft crash (alpha)	(EU)	2.4E-02	5.6E-07	3.1E-03	8.0E-02	1.9E-06	1.1E-02
Incineration, earthquake (nonalpha)	(VU)	3.2	7.5E-05	4.0E-01	1.1E+01	2.5E-04	1.4
Incineration, earthquake (alpha)	(VU)	1.6E-02	3.7E-07	2.1E-03	5.4E-02	1.3E-06	7.3E-03
Incineration, incinerator explosion (nonalpha)	(A)	1.9E-03	4.5E-08	2.4E-01	6.5E-03	1.5E-07	8.5E-01
Incineration, incinerator explosion (alpha)	(A)	9.5E-06	2.2E-10	1.3E-03	3.2E-05	7.6E-10	4.4E-03
Incineration, baghouse area fire (nonalpha)	(U)	4.8E-02	1.1E-06	6.0E-03	1.6E-01	3.8E-06	2.1E-02
Incineration, baghouse area fire (alpha)	(U)	2.4E-04	5.6E-09	3.1E-05	8.0E-04	1.9E-08	1.1E-04
Maximum reasonably foreseeable accident		4.8	1.1E-04	6.0E-01	1.6E+01	3.8E-04	2.1

[a] Indicates cancer fatality and incidence associated with radiation exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1E-02), "U" for unlikely (1E-04 to 1E-02), "VU" for very unlikely (1E-06 to 1E-04), and "EU" for extremely unlikely (< 1E-06).

D.3.2.8 Summary of the LLW Accident Analysis Results

For all receptors, the dominating accidents are those involving a large airplane crash or an earthquake during incineration (nonalpha). At any installation where both of these accident types are analyzed, the risks associated with them differ by less than a factor of two for offsite and noninvolved worker populations, offsite and noninvolved worker MEIs, and workers. The risks to all receptors from alpha facility accidents are generally lower than the comparable nonalpha facility accident risks at a given installation by about 2 orders of magnitude. This is due to a much smaller inventory of alpha LLW and therefore, much smaller releases associated with alpha incinerator accidents. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

D.3.2.8.1 *Risks to the Offsite Population From LLW Accidents*

The lowest installation-specific health risks associated with accidents are for the incinerator explosion at INEL in No Action and Regionalized 2 (2.4E–08 cancer fatalities) and for the same accident at FEMP (3.6E–03 cancer fatalities) and PORTS (1.5E–08 cancer fatalities) in Regionalized 2. The highest accident risks are at Hanford in Centralized 5 for the large airplane crash scenario (4.8 cancer fatalities) and for the earthquake scenario (3.2 cancer fatalities) and at LLNL and LANL in Regionalized 2 for the earthquake during incineration (2.9 and 8.7E–01 cancer fatalities, respectively). The comparatively high risks to these populations are due to the combination of population distribution and waste inventory at each installation. The cancer fatality risk from the maximum reasonably foreseeable accident at Hanford in Centralized 5 increases about 3 orders of magnitude compared to that in Regionalized 2 due to waste consolidation.

In general, the airplane crash (small and large) and the earthquake with subsequent fire are the worst-case accidents in all alternatives and vary by less than 1 order of magnitude at all sites where both accident types are postulated. The associated annual frequencies for these accidents differ somewhat in that an airplane crash is considered "extremely unlikely" (less than 1.0E–06 per year) and an earthquake is considered "very unlikely" (1.0E–06 to 1.0E–04 per year).

The principal contributors to risk are uranium-238 at FEMP, Hanford (Centralized 5), LANL, PGDP, PORTS, and SRS; thorium-232 at LLNL and ORR; cesium-137 at Hanford (Regionalized 2); cobalt-60 at INEL; and plutonium-238 at Hanford (alpha incineration only in Centralized 5) and RFETS. The primary exposure route is internal exposure in all alternatives.

D.3.2.8.2 *Risks to the Noninvolved Worker Population From LLW Accidents*

Noninvolved worker risks are slightly lower than offsite population risks, but are distributed over a much smaller affected population. The general trend in risks by accident type, dominating accident type, controlling contaminants and exposure route, and highest-risk sites are the same as for offsite population.

D.3.2.8.3 *Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From LLW Accidents*

Radiological risks to the offsite and noninvolved worker MEIs generally parallel the trends for their respective populations but are 2 to 5 orders of magnitude lower. For the noninvolved worker MEI, the highest cancer fatality risks are at Hanford in Centralized 5 (9.2E–03) and at LLNL and LANL in Regionalized 2 (3.6E–04 and 7.4E–04, respectively). The highest cancer fatality risks to the offsite MEI are at LLNL and LANL in Regionalized 2 (4.0E–04 and 4.1E–04, respectively) and at Hanford in Centralized 5 (1.1E–04). The cancer risks to the offsite population in Regionalized 2 are among the highest primarily because of the relatively large contaminant releases in the accidents at LANL and LLNL combined with the relatively large number of residents living very close to each of these sites (ORNL, 1995d). The cancer risks in Centralized 5 are among the highest primarily because of the large volume of waste consolidated at Hanford (higher than the cancer risks to MEIs in Regionalized 2 by almost 4 orders of magnitude).

Controlling contaminants for both MEIs at these three sites are the same as for their respective populations, uranium-238 at LANL and Hanford and thorium-232 at LLNL. The exposure route is internal exposure for both receptors at all sites.

D.3.2.8.4 *Risks to Waste Management Workers From LLW Accidents*

The cancer fatality risks to workers from maximum reasonably foreseeable accidents range from 3.6E–07 to 6.0E–01; shift size varies from one to eight workers. In all alternatives, the large aircraft crash into an incinerator and an earthquake at an incinerator are the highest-risk accidents. For any installation where both of these accident types were analyzed, the difference in risks between them is less than a factor of two. The next highest accident risks to workers are associated with the incinerator explosion scenario. (If the large aircraft crash is not postulated for an installation, then the earthquake and incinerator explosion scenarios are the highest-risk accident types; cancer risks differ by less than a factor of two for these two scenarios.) Risks from the baghouse fire scenario are generally 1 or more orders of magnitude lower than those associated with the aircraft crash, earthquake, and incinerator explosion scenarios. The accident types that result in higher risks to workers involve larger releases of radionuclides than the baghouse fire scenario. Recall that the estimated annual frequency of the aircraft crash accidents occurring is "extremely unlikely" (less than 1.0E–06 per year); the earthquake scenario is considered "very unlikely" (1.0E–06 to 1.0E–04 per year); the baghouse fire is considered "unlikely" (1.0E–04 to 1.0E–02 per year); and the incinerator explosion is "anticipated" (greater than 1.0E–02 per year).

The highest worker cancer fatality risk is for the maximum reasonably foreseeable accident at Hanford in Centralized 5. The cancer fatality risk at Hanford in Centralized 5 is about 5 orders of magnitude higher than at Hanford in Regionalized 2 due to the consolidation of LLW for treatment at Hanford (which would result in a larger release in the event of an accident). Exposure to uranium-238 via inhalation is the risk driver at Hanford in Centralized 5. The highest-risk sites in No Action and Regionalized 2 are SRS and LANL (Regionalized 2 only). Worker cancer fatality risks at the other sites are lower by 1 to 6 orders of magnitude. Inhalation of uranium-238 is also the driving contributor to worker risk at SRS and LANL in No Action and Regionalized 2.

D.3.2.9 Risks to the Hypothetical Intruder From LLW Disposal

The health risks to the hypothetical intruder who drills a well through an LLW disposal facility were evaluated for the Decentralized, Regionalized 3, and Centralized 1 Alternatives, for intrusion 100 years and 300 years after the cessation of disposal activities at each installation. Tables D.3.2–76 and D.3.2–77 present summaries of the risk evaluations at 100 and 300 years, respectively. Tables D.3.2–78 through D.3.2–83 contain the health risks by health endpoint and installation for each alternative in both time frames.

Table D.3.2–76. Summary Table for the Intruder Scenario for LLW (100 years)

Alternative	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Decentralized	160	8.0E–02	2.7E–01	1.6E–02
Regionalized 3	110	5.3E–02	1.8E–01	1.1E–02
Centralized 1	1.7	8.3E–03	2.8E–02	1.7E–03

Table D.3.2–77. Summary Table for the Intruder Scenario for LLW (300 years)

Alternative	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Decentralized	1.7	8.4E–04	2.8E–03	1.7E–04
Regionalized 3	1.1	5.7E–04	1.9E–03	1.1E–04
Centralized 1	1.7E–01	8.4E–05	2.9E–04	1.7E–05

Table D.3.2-78. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)

Site	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
ANL-E	6.6E-01	3.3E-04	1.1E-03	6.6E-05
Hanford	6.8	3.4E-03	1.2E-02	6.8E-04
INEL	7.0E-01	3.5E-04	1.2E-03	7.0E-05
LANL	142	7.1E-02	2.4E-01	1.4E-02
LLNL	5.8	2.9E-03	9.8E-03	5.8E-04
ORR	1.3	6.6E-04	2.2E-03	1.3E-04
PGDP	6.7E-03	3.3E-06	1.1E-05	6.7E-07
Pantex	5.2E-03	2.6E-06	8.9E-06	5.2E-07
PORTS	4.8E-01	2.4E-04	8.2E-04	4.8E-05
RFETS	2.4E-03	1.2E-06	4.1E-06	2.4E-07
SNL-NM	1.5	7.3E-04	2.5E-03	1.5E-04
SRS	2.3	1.2E-03	4.0E-03	2.3E-04
Total	160	8.0E-02	2.7E-01	1.6E-02

Table D.3.2-79. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)

Site	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
ANL-E	7.6E-03	3.8E-06	1.3E-05	7.6E-07
Hanford	5.8E-02	2.9E-05	9.9E-05	5.8E-06
INEL	1.3E-01	6.6E-05	2.2E-04	1.3E-05
LANL	1.2	5.9E-04	2.0E-03	1.2E-04
LLNL	1.0E-01	5.0E-05	1.7E-04	1.0E-05
ORR	1.1E-02	5.3E-06	1.8E-05	1.1E-06
PGDP	6.6E-03	3.3E-06	1.1E-05	6.6E-07
Pantex	5.2E-03	2.6E-06	8.9E-06	5.2E-07
PORTS	1.2E-01	6.0E-05	2.0E-04	1.2E-05
RFETS	1.9E-03	9.5E-07	3.2E-06	1.9E-07
SNL-NM	2.6E-02	1.3E-05	4.4E-05	2.6E-06
SRS	2.6E-02	1.3E-05	4.5E-05	2.6E-06
Total	1.7	8.4E-04	2.8E-03	1.7E-04

Table D.3.2-80. Intruder Scenario Risk Results for Regionalized Alternative 3 (100 years)

Site	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	6.8	3.4E-03	1.2E-02	6.8E-04
INEL	7.0E-01	3.5E-04	1.2E-03	7.0E-05
LANL	91	4.5E-02	1.5E-01	9.1E-03
NTS	5.8	2.9E-03	9.8E-03	5.8E-04
ORR	8.1E-01	4.1E-04	1.4E-03	8.1E-05
SRS	2.3	1.2E-03	4.0E-03	2.3E-04
Total	110	5.3E-02	1.8E-01	1.1E-02

Table D.3.2-81. Intruder Scenario Risk Results for Regionalized Alternative 3 (300 years)

Site	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	5.8E-02	2.9E-05	9.9E-05	5.8E-06
INEL	1.3E-01	6.6E-05	2.2E-04	1.3E-05
LANL	7.6E-01	3.8E-04	1.3E-03	7.6E-05
NTS	1.0E-01	5.0E-05	1.7E-04	1.0E-05
ORR	6.1E-02	3.0E-05	1.0E-04	6.1E-06
SRS	2.6E-02	1.3E-05	4.5E-05	2.6E-06
Total	1.1	5.7E-04	1.9E-03	1.1E-04

Table D.3.2-82. Intruder Scenario Risk Results for Centralized Alternative 1 (100 years)

Site	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	1.7	8.3E-03	2.8E-02	1.7E-03
Total	1.7	8.3E-03	2.8E-02	1.7E-03

Table D.3.2-83. Intruder Scenario Risk Results for Centralized Alternative 1 (300 years)

Site	Radionuclides			
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects
Hanford	1.7E-01	8.4E-05	2.9E-04	1.7E-05
Total	1.7E-01	8.4E-05	2.9E-04	1.7E-05

D.3.2.9.1 *Results of the Human Health Risk Analysis for the Intruder*

In the Decentralized Alternative, LLW is disposed of at 12 sites. One hundred years after the end of disposal operations, the highest intruder cancer fatality risk is at LANL (7.1E–02). This is due to both the large volume of waste disposed at LANL in this alternative and the presence of strontium-90 in the inventory. Strontium is a bone-seeking radionuclide; hence, its internal dose conversion factors are high.

The lowest intruder cancer fatality risk is at RFETS (1.2E–06), which disposes of only its own waste in this alternative. Three hundred years after disposal operations end, the highest and lowest intruder risks are still at LANL (5.9E–04) and RFETS (9.5E–07), respectively; strontium-90 continues to be the driving contaminant at LANL. In the Regionalized Alternative 3, LLW is consolidated and disposed of at six sites. One hundred years after the completion of disposal operations, the highest intruder cancer fatality risk is at LANL (4.5E–02). Again, this is due to the large volume of waste that is disposed of and the presence of strontium-90 in the inventory. In Regionalized 3, LANL receives waste from SNL-NM, Pantex, and RFETS. The lowest intruder cancer fatality risk is at INEL (3.5E–04), which disposes of only its own waste. Three hundred years after the end of disposal operations, the highest intruder cancer fatality risk remains at LANL (3.8E–04). The lowest intruder cancer fatality risk is at SRS (1.3E–05), which receives waste from Pinellas. INEL is no longer the lowest-risk installation because of the accumulation of higher-risk daughter (radioactive decay) products at this installation during the intervening 200 years.

In the Centralized Alternative 1, all LLW is consolidated and disposed of at Hanford. One hundred years after disposal operations end, the intruder's risk of cancer fatality is 8.3E–03. Three hundred years after disposal operations, the risks are 2 orders of magnitude lower.

Overall, Centralized 1 results in the lowest collective risks to the intruder among the three alternatives. This result may seem counterintuitive. However, when relatively low-activity wastes from other sites are added to the higher-activity Hanford wastes, the resulting *average* waste concentration at Hanford is lower than in Decentralized and Regionalized 3. Consequently, the risks to the intruder are lowest in Centralized 1.

D.3.3 HAZARDOUS WASTE

Hazardous waste (HW) is broadly defined in the Resource Conservation and Recovery Act (RCRA) as a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may: (1) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (2) pose a substantial or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

The EPA has more specifically defined and identified HW according to considerations such as acute and chronic toxicity, persistence, and degradability in nature; potential for bioaccumulation; and other characteristics such as ignitability, corrosiveness, and reactivity. Based on these factors, the EPA promulgated regulations under 40 CFR 261, classifying HW as "listed" waste, "characteristic" waste, or "other" waste. Listed wastes are those specifically identified on one of the lists in 40 CFR 261, Subpart D. These include wastes from nonspecific sources, wastes from specific sources or industries, and a rigidly defined list of commercial chemical products. Examples of listed wastes are spent solvents, spent sludges, and discarded commercial chemicals such as cyanides, benzene, and chloroform. Characteristic wastes are defined by 40 CFR 261, Subpart C, as exhibiting ignitability, corrosiveness, reactivity, or toxicity. Other HW includes mixtures that contain HW and residues from HW treatment. HW contains no radioactive component; wastes that meet the RCRA definition of HW and are also radioactive are addressed as low-level mixed waste (see Section D.3.5).

HW is generated by a variety of DOE activities including those associated with defense, nuclear energy, and energy research programs. The following 11 sites generate the majority of the DOE inventory of HW and are considered in this human health risk evaluation (note that the abbreviations given here are used throughout this appendix):

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Hanford Site (Hanford), Richland, Washington
- Fermi National Accelerator Laboratory (Fermi), Batavia, Illinois
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Kansas City Plant (KCP), Kansas City, Missouri
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Lawrence Livermore National Laboratory (LLNL), Livermore, California

- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Pantex Plant (Pantex), Amarillo, Texas
- Sandia National Laboratories-New Mexico (SNL-NM), Albuquerque, New Mexico
- Savannah River Site (SRS), Aiken, South Carolina

The quantities and types of HW generated vary throughout the DOE complex. Laboratory facilities generate wastes (e.g., laboratory solutions, acids, and caustics) as a result of research and development activities, processing operations, and other activities associated with their mission. Production facilities generate HW as a result of manufacturing weapons and weapons materials, nuclear fuel, and other production operations. Many sites also generate reportable quantities of industrial solvents, paints, oils, rags, and wipes contaminated with hazardous cleaning compounds, and other hazardous materials that are byproducts of routine maintenance, degreasing, and machine-shop operations (ANL, 1996d). The current HW management strategy is based on minimizing (or eliminating) HW generation, and on proper characterization, treatment, and disposal.

Environmental restoration activities also contribute substantially to HW generation. While an installation may produce very little HW in the course of routine operations, remediation of environmental problems such as leaking petroleum underground storage tanks may generate thousands of pounds of HW-contaminated soil.

For more detailed information on HW, including HW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, and the process for developing PEIS HW alternatives, see Chapters 3 and 10 of the PEIS and the HW technical report (ANL, 1996d).

D.3.3.1 Summary of HW Alternatives

The PEIS waste management alternatives (No Action, Regionalized 1 and 2) and the rationale for developing the various HW analysis alternatives are discussed rigorously in the main body of the PEIS.

- The No Action Alternative demonstrates the baseline risks of treating some of the DOE inventory of HW by incineration only (no waste fuel burning) at existing facilities at INEL and the ORR, while the remainder is treated by permitted commercial facilities.

- In the Regionalized Alternative 1, approximately 50% of the complexwide, commercially treated HW is instead treated by incineration and waste fuel burning at Hanford, INEL, LANL, ORR, and SRS. The remaining HW is treated and disposed of by permitted commercial facilities.
- In the Regionalized Alternative 2, approximately 80% to 90% of the complexwide, commercially treated HW is instead treated by incineration and waste fuel burning at INEL and ORR. The remainder is treated and disposed of by a limited number of permitted commercial facilities.

Table D.3.3-1 presents the consolidation and treatment schemes for these three alternatives.

Note that Section 10.3 of Volume I describes a Decentralized Alternative for HW management. The main difference between the No Action and Decentralized Alternatives is a 6% shift in the waste totals for thermal treatment and fuel substitution from offsite treatment, under the No Action Alternative, to onsite treatment, under the Decentralized Alternative. Because of this relatively small difference, the potential impacts of these two alternatives are expected to be quite similar. Therefore, health risk estimates for the Decentralized Alternative are not presented in this section of the WM PEIS. However, Section 10.4 of Volume I and the Volume II site data tables include risk estimates for the Decentralized Alternative, which are the same as those presented for the No Action Alternative.

D.3.3.2 Special Assumptions and Considerations Used in the HW Risk Analysis

The source term for chlorinated organics and inorganics emitted in incinerator flue gases was developed from a set of RCRA trial burn data from the Rollins Deer Park, Texas, waste incinerator (one of the commercial facilities that currently processes DOE-generated HW); the constituents in the flue gases are shown in Table D.3.3-2. Although the chemistry of the industrial wastes used in the trial burn was unknown, they were waste types generally typical of DOE HW and were assumed to be reasonably similar to DOE HW in organic composition (ANL, 1996d). The results of those burns were scaled up based on each installation's HW waste volume.

It was assumed that the composition of HW and the relative proportions of its components are the same at all sites. Because of this, the controlling contaminants and their percentage contribution to risk are the same across all sites and alternatives.

Table D.3.3–1. PEIS Alternatives for HW

Alternative	ANL-E	Hanford	Fermi	INEL	KCP	LANL	LLNL	ORR	Pantex	SNL-NM	SRS
No Action—Treatment of own HW (by incineration) at current 2 sites; remainder treated commercially				T				T			
Regionalized 1—50% of DOE HW treated (by incineration and fuel burning) at 5 sites; remainder treated commercially		T		T		T		T			T
Regionalized 2—80-90% of DOE HW treated (by incineration and fuel burning) at 2 sites; remainder treated commercially				T				T			

Note: T = treatment installation.

Table D.3.3–2 HW Source Term Constituents Derived From Analysis of Deer Park, Texas, Incinerator Flue Gases

Constituents in HW Source Term	
Bromodichloromethane	Chlorine
Chlorobenzene	Vinyl chloride
Chloromethane	Cadmium
Chloroform	Chromium (VI)
Dibromochloromethane	Copper
1,2-Dichloroethane	Lead
Methylene chloride	Mercury
1,1,2,2-Tetrachloroethane	Nickel
1,1,1-Trichloroethane	Zinc
1,1,2-Trichloroethane	Arsenic
Trichlorofluoromethane	Dioxins (PCDD)
Hydrogen chloride	Furans (PCDF)

Consistent with the other waste streams, the duration of the No Action Alternative is assumed to be 20 years. For the Regionalized 1 and 2 Alternatives, construction of treatment facilities is assumed to take place for 10 years and HW treatment for 10 years.

The RfDs/RfCs and cancer potency factors for the various HW constituents, where available, were obtained from the EPA's Health Effects Assessment Summary Tables and Integrated Risk Information System. If the EPA values were not available, toxicity values derived by PNL were used (Droppo et al., 1989).

It was assumed that an FTE (see Section D.2) would not be exposed to concentrations of hazardous chemicals that exceed the time-weighted average threshold limit value (TWA-TLV) for full-time workers exposed 8 hours/day, 40 hours/week (ACGIH, 1992).

The chemicals used as surrogates in evaluating the health effects to the public from polychlorinated dibenzo-dioxins and polychlorinated dibenzofurans were hexachlorodibenzo-p-dioxin and hexachlorodibenzofuran, respectively. Due to the lack of better information, it was also assumed that the chromium in the source term was present as 100% chromium (VI), an inhalation carcinogen. This is a conservative assumption; therefore, health risks associated with chromium in the HW source term may be overestimated.
No TLVs or immediately-dangerous-to-life-and-health (IDLH) values were found for bromodichloro-methane, dibromochloromethane, hexachlorodibenzofuran, or hexachlorodibenzo-p-dioxin; therefore, the health effects to workers associated with these chemicals were not evaluated. However, the first two compounds comprise only 0.01% each of the source term, the third is 2.6E-05% of the source term, and the fourth is 3E-06% of the source term. The offsite and noninvolved worker populations were evaluated for all chemicals in the source term.

Note that the human health risks for commercial treatment are not addressed in this analysis. Therefore, the greater the percentage of waste treated commercially, the lower the human health risk estimates for the DOE complex and the less information this analysis can supply about the overall risks to human health from combined public and private HW waste management activities.

D.3.3.3 Results Tables for the HW Human Health Risk Analysis

This section contains the results tables for the HW human health risk analysis. A discussion of the results is presented in Section D.3.4.4. The risks in the tables are displayed in the standard scientific (exponential) notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.3–3 presents an overview, by alternative, of the *total*, programwide risks of cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer incidence and construction and operational fatalities for waste management workers. These tables provide the estimated *total number* of people in the three receptor populations who will develop cancers from exposure to HW over a lifetime if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.3–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.3–5 summarizes the risks to the offsite and noninvolved worker MEIs for each HW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will develop cancer from chemical exposure or are indicators that the MEIs will suffer adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.3–6 through D.3.3–8 show the programwide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.3–9 through D.3.3–11 present offsite and worker population risks for each installation, by alternative.
- Table D.3.3–12 lists the hazardous constituents that contribute most of the risk of cancer incidence to the offsite population, by installation and alternative.

Table D.3.3–3 Summary of Programwide Risks Associated With Routine Management of HW: Risks to Total Populations, by Alternative

Alternative	Offsite Population	WM Workers		Noninvolved Worker Population
	Chem CI	Chem CI	C&OF	Chem CI
No Action	7.5E-03	9.4E-02	8.2E-03	2.5E-03
Regionalized 1	6.0E-02	1.2	6.9E-02	2.5E-02
Regionalized 2	9.6E-02	1.8	7.3E-02	3.3E-02

Notes: Chem CI = cancer incidence associated with exposure to hazardous chemicals; C&OF = fatalities due to physical hazards during construction and operation of waste treatment facilities.

Table D.3.3-4 Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by the Risks From Routine Management of HW, by Alternative

Alternative	Offsite Population	WM Workers	Noninvolved Worker Population
No Action	1,034,713	52	12,260
Regionalized 1	2,192,128	355	48,482
Regionalized 2	1,034,713	372	12,260

Table D.3.3-5 Summary of Programwide Risks Associated With Managing HW to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative

Alternative	Offsite MEI		Noninvolved Worker MEI	
	Chem CI	HI	Chem CI	HI
No Action	3.9E-07	2.6E-03	2.4E-06	1.6E-02
Regionalized 1	2.4E-06	3.2E-02	1.1E-05	5.1E-01
Regionalized 2	5.0E-06	6.6E-02	3.1E-05	4.1E-01

Notes: MEI = maximally exposed individual; Chem CI = cancer incidence associated with exposure to hazardous chemical.
HI = hazard index.

Table D.3.3-6 Programwide Risks Associated With the Routine Management of HW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)			
	Cancer fatalities			
	Cancer incidence	2.5E-03		
	Genetic effects			
Noninvolved worker MEI	Dose (rem)			
	Cancer fatalities			
	Cancer incidence	2.4E-06		
	Genetic effects			
	Hazard index		1.6E-02	
Offsite population	Dose (person-rem)			
	Cancer fatalities			
	Cancer incidence	7.5E-03		
	Genetic effects			
Offsite MEI	Dose (rem)			
	Cancer fatalities			
	Cancer incidence	3.9E-07		
	Genetic effects			
	Hazard index		2.6E-03	
WM workers	Dose (FTE-rem)			
	Cancer fatalities			
	Cancer incidence	9.4E-02		
	Genetic effects			
	Exposure index		4.3	
	Construction fatalities			1.9E-03
	Construction injuries			8.4E-01
	Operation fatalities			6.3E-03
	Operation injuries			5.3

Table D.3.3-7. Programwide Risks Associated With the Routine Management of HW Under Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem) Cancer fatalities Cancer incidence Genetic effects	2.5E-02		
Noninvolved worker MEI	Dose (rem) Cancer fatalities Cancer incidence Genetic effects Hazard index	1.1E-05	 1.5E-01	
Offsite population	Dose (person-rem) Cancer fatalities Cancer incidence Genetic effects	6.0E-02		
Offsite MEI	Dose (rem) Cancer fatalities Cancer incidence Genetic effects Hazard index	2.4E-06	 3.2E-02	
WM workers	Dose (FTE-rem) Cancer fatalities Cancer incidence Genetic effects Exposure index Construction fatalities Construction injuries Operation fatalities Operation injuries	1.2	 6.1	 2.6E-02 1.2E+01 4.3E-02 3.7E+01

Table D.3.3-8. Programwide Risks Associated With the Routine Management of HW Under Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Hazardous Chemicals		Physical Hazards
		Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem) Cancer fatalities Cancer incidence Genetic effects	3.3E-02		
Noninvolved worker MEI	Dose (rem) Cancer fatalities Cancer incidence Genetic effects Hazard index	3.1E-05	 4.1E-01	
Offsite population	Dose (person-rem) Cancer fatalities Cancer incidence Genetic effects	9.6E-02		
Offsite MEI	Dose (rem) Cancer fatalities Cancer incidence Genetic effects Hazard index	5.0E-06	 6.6E-02	
WM workers	Dose (FTE-rem) Cancer fatalities Cancer incidence Genetic effects Exposure index Construction fatalities Construction injuries Operation fatalities Operation injuries	1.8	 6.2	 2.8E-02 1.2E+01 4.5E-02 3.8E+01

Table D.3.3-9. Risks Associated With the Routine Management of HW Under the No Action Alternative, by Site

Site	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI	Noninvolved Worker Population	Noninvolved Worker MEI	Workers
INEL	153,061 16	2.6E-03	3.4E-05	4.6E-09	4.4E-05	3.7E-08	1.8E-02
ORR	881,652 36	5.6E-03	7.4E-03	3.9E-07	2.5E-03	2.4E-06	7.6E-02
Total		8.2E-03	7.5E-03	3.9E-07	2.5E-03	2.4E-06	9.4E-02

Note: MEI = maximally exposed individual.
[a] Top number represents the offsite population within an 80-km (50-mi) radius of the site, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.

Table D.3.3-10. Risks Associated With the Routine Management of HW Under Regionalized Alternative 1, by Site

Site	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI	Noninvolved Worker Population	Noninvolved Worker MEI	Workers
Hanford	377,645 91	1.8E-02	4.3E-03	1.4E-07	2.6E-03	5.0E-06	2.9E-01
INEL	153,061 35	6.8E-03	1.0E-04	1.4E-08	1.4E-04	1.1E-07	7.6E-02
LANL	159,152 88	1.7E-02	1.9E-02	2.4E-06	9.5E-03	5.9E-06	3.0E-01
ORR	881,652 101	2.0E-02	3.6E-02	1.8E-06	1.1E-02	1.1E-05	4.2E-01
SRS	620,618 40	7.9E-03	1.2E-03	1.5E-08	5.9E-04	6.7E-07	9.3E-02
Total		6.9E-02	6.0E-02	2.4E-06	2.5E-02	1.1E-05	1.2

Note: MEI = maximally exposed individual.
[a] Top number represents the offsite population within an 80-km (50-mi) radius of the site, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.

Table D.3.3–11. Risks Associated With the Routine Management of HW Under Regionalized Alternative 2, by Site

Site	Population[a]	Fatalities[b]	Cancer Incidence				
		Workers	Offsite Population	Offsite MEI	Noninvolved Worker Population	Noninvolved Worker MEI	Workers
INEL	153,061 160	3.1E-02	9.7E-04	1.3E-07	1.3E-03	1.1E-06	7.4E-01
ORR	881,652 212	4.1E-02	9.5E-02	5.0E-06	3.2E-02	3.1E-05	1.1
Total		7.3E-02	9.6E-02	5.0E-06	3.3E-02	3.1E-05	1.8

Note: MEI = maximally exposed individual.
[a] Top number represents the offsite population within an 80-km (50-mi) radius of the installation, while the bottom number represents the total FTEs for waste management workers involved in both construction and operation activities.
[b] Risk of cancer fatality from exposure to hazardous chemicals cannot be assessed; worker fatality risks reflect risks from physical hazards only.

Table D.3.3–12. Constituents in HW Contributing the Highest Risk of Cancer Incidence to the Offsite Population at Each Site, by Alternative

Alternative	Installation				
	Hanford	INEL	LANL	ORR	SRS
No Action	—	Chromium (VI)[a] 2.7E-05[b]	—	Chromium (VI) 5.9E-03	—
Regionalized 1	Chromium (VI) 3.5E-03	Chromium (VI) 8.3E-05	Chromium (VI) 1.5E-02	Chromium (VI) 2.9E-02	Chromium (VI) 9.4E-04
Regionalized 2	—	Chromium (VI) 7.8E-04	—	Chromium (VI) 7.7E-02	—

[a] Chromium in the source term was assumed to be 100% chromium (VI).
[b] Risk of cancer incidence contributed by this constituent.

D.3.3.4 Results of the HW Human Health Risk Analysis for Routine Operations

The following sections present a summary of the estimated programwide impacts to each receptor population and a discussion of the overall results of the HW human health risk analysis.

D.3.3.4.1 *Programwide Trends in Human Health Risks Associated With HW Management Alternatives*

Offsite Population. For the offsite population, the programwide risk of cancer incidence associated with routine treatment of HW is lowest for No Action (7.5E-03 cancer incidences distributed over a total affected population of approximately 1 million), and slightly higher for Regionalized 1 and 2 (6.0E-02 over a total population of approximately 2 million and 9.6E-02 over approximately 1 million, respectively). As would be expected based on the waste consolidation and treatment scenarios, cancer incidence risks at INEL and ORR are slightly higher in Regionalized 2 than Regionalized 1 (recall that in Regionalized 2,80% to 90% of the DOE inventory of commercially treatable HW is consolidated and treated at these two sites).

Noninvolved Worker Population. The programwide risk of cancer incidence to the noninvolved worker population follows the same pattern as for the offsite population: Regionalized 1 and 2 risks are similar to one another (both are in the E-02 order of magnitude) and approximately 1 order of magnitude higher than in No Action. However, the total affected noninvolved worker populations (approximately 12,260 in No Action and Regionalized 2 and 48,482 in Regionalized 1) are substantially smaller than the total offsite populations. Therefore, the relative risks "per capita" (the risks to an average member of the noninvolved worker population compared to an average member of the offsite population) are concomitantly higher. This higher individual risk to members of the noninvolved worker population is also reflected in the results for the offsite and noninvolved worker MEIs.

Maximally Exposed Noninvolved Worker and Offsite Individual. For the offsite and noninvolved worker MEIs, risk of cancer incidence follows the same pattern as for their respective populations. However, the risks of cancer incidence for both of these receptors in Regionalized 1 and 2 are in the E-05 to E-06 range.

Most of the MEI risk in these alternatives is attributable to the presence of the inhalation carcinogen chromium (VI) in the source term (ANL, 1996d). The hazard indices for both MEIs (indicating the greatest individual exposure to noncarcinogenic chemicals per scenario) follow the trend for cancer incidence but are less than 1.0 in all alternatives. This indicates a low probability that these receptors will suffer adverse effects from exposure to noncarcinogenic, toxic contaminants.

Workers. Programwide health risks to workers follow the same general trends as for the offsite and noninvolved worker populations. The total risks of cancer incidence in Regionalized 1 and 2 are slightly more than 1 order of magnitude higher than in No Action, and range from 1.8E-02 to 1.1. While the air concentrations of each HW constituent component are estimated to be at or below TLVs, the sum of the exposures from those concentrations yields exposure indices that are consistently above 1.0 (ranging from 4.1 to 8.2) in all alternatives. This indicates that the worker receiving the worst-case exposure is potentially at risk of adverse health effects from the daily inhalation of fugitive chemical emissions in all three alternatives. These results indicate that the risk of cancer incidence to the total worker population increases as a greater percentage of the DOE HW inventory is treated and as treatment is performed at fewer consolidation sites, while the highest individual exposure to hazardous, noncarcinogenic chemicals differs little from alternative to alternative.

As can be seen in Tables D.3.3-9 through D.3.3-11, the highest risks of cancer incidence to workers result at INEL and ORR under Regionalized 2, in which these two sites treat 80% to 90% of the DOE inventory of commercially treatable HW. The difference in risks at these sites between Regionalized 1 and 2 is about 0.5 to 1 order of magnitude.

Construction and operational injuries and fatalities follow the same pattern as exposure risks to workers and other populations (see Tables D.3.3-6 through D.3.3-8). No Action involves the least construction, the smallest volume of waste in treatment, and the fewest workers. Accordingly, the No Action risks from physical hazards are the lowest among the three alternatives. The risks from physical hazards in Regionalized 1 and 2 are almost identical to one another and reflect increased person-hours spent building and operating waste processing facilities compared to No Action.

D.3.3.4.2 *Summary of Results for Routine Treatment of HW*

For the offsite population, ORR poses the highest risk of cancer incidence in No Action and Regionalized 2; ORR and LANL pose the highest risks in Regionalized 1 (see Tables D.3.3–9 through D.3.3–11). INEL presents the lowest cancer incidence risks in all alternatives. Inhaled chromium (VI) contributes the most risk of cancer incidence to the offsite population at all sites across all alternatives (see Table D.3.3–12). Cancer incidence risks to the offsite MEI are in the E–06 order of magnitude at LANL in Regionalized 1 and ORR in Regionalized 1 and 2.

Risks to the various noninvolved worker populations tend to parallel the risks to the site-specific offsite populations. ORR presents the highest risk of cancer incidence in No Action and Regionalized 2; and ORR, LANL, and Hanford pose the highest risks in Regionalized 1. Inhalation of chromium (VI) contributes most of the cancer incidence risk at all sites in all alternatives (ORNL, 1996).

The cancer incidence risk to the noninvolved worker MEI is between 1.0E–06 and 1.0E–04 at ORR in No Action; ORR, LANL, and Hanford in Regionalized 1; and ORR and INEL in Regionalized 2. Hazard indices for both MEIs are below 1.0 in all alternatives, indicating a low probability of adverse effects from exposure to noncarcinogenic, toxic contaminants.

The highest site cancer incidence risks are always at ORR for workers, although differences between sites in cancer incidence for workers are consistently less than 1 order of magnitude. The controlling contaminants at ORR for worker cancer incidence are chromium (VI) in No Action and vinyl chloride and chromium (VI) in Regionalized 1 and 2. In No Action, the exposure index at ORR is slightly higher than at INEL; the controlling contaminants at ORR are chlorine and cadmium. In Regionalized 1 and 2, exposure indices at all sites are approximately equal; controlling contaminants are hydrogen chloride, chlorine, cadmium, copper, lead, and nickel.

D.3.3.4.3 *Discussion*

As noted in the summary of HW alternatives (Section D.3.3.1), No Action involves only the incineration of the INEL and ORR inventories of HW, while Regionalized 1 and 2 involve treatment of consolidated HW waste loads (50% and 80 to 90%, respectively) by incineration and waste fuel burning. Accordingly,

risks to the various receptors would be expected to increase as the amount of waste treated at DOE sites and the degree of consolidation increase. While the differences among alternatives are relatively small, this trend is apparent. Health risks associated with Regionalized 1 and 2 are slightly higher than those associated with No Action by about 1 order of magnitude. The risks for Regionalized 1 and 2 are approximately the same for all populations and health effects endpoints. In other words, treating 50% of the DOE inventory of HW at five sites and treating 80% to 90% at two sites results in nearly the same overall health risks to all populations. Within each alternative, the highest-risk sites for exposure are also the highest-risk sites for construction and operational risks. This indicates that the volume of waste being treated and, consequently, the number of hours workers spend constructing facilities and processing the waste, are the determining factors for health risks.

Comparison of the risks to the overall populations and MEIs in Regionalized 1 and 2 (see Tables D.3.3–10 and D.3.3–11) shows that risks generally differ by less than a factor of 2 between the two alternatives (which is reasonable since the difference in the amount of waste processed does not quite double between the alternatives). However, the risks in Regionalized 1 are distributed over twice as many members of the offsite population and four times as many members of the noninvolved worker population as in Regionalized 2.

D.3.3.5 Summary of Alternatives for Potential HW Accidents

Three categories of potential HW accidents were analyzed for Regionalized 1 and 2: single-drum, single-contaminant accidents occurring during storage; multiple-contaminant storage facility accidents; and multiple-contaminant treatment facility accidents.

D.3.3.5.1 *Single-Drum Accidents*

Thirty-one storage accidents involving the release of a single chemical (either a carcinogen or a hazardous noncarcinogen) from a single drum were postulated for each site and each alternative. These single-drum accident scenarios are summarized in Table D.3.3–13.

There were three general types of single-drum accidents: a spill; a spill plus fire; and other combinations of events (spill plus explosion, fire only, fire plus explosion, etc.). Because of the large number of accidents to be analyzed, only the results of the four accidents for which the attendant risks are highest at each site for each alternative are reported in Table D.3.3–15, which can be found in Section D.3.3.7. These results are:

- The estimated cancer incidence in the site's offsite population for an accident involving a carcinogen.
- The hazard index for the offsite MEI for an accident involving a hazardous noncarcinogen.
- The estimated cancer incidence for the shift of six FTEs (hypothetical workers) working during an accident involving a carcinogen.
- The IDLH index (see Section D.2.11) for the maximally exposed FTE working during an accident involving a hazardous noncarcinogen.

The consequences of a single-drum accident release (if the accident occurred) do not differ among alternatives. However, the estimated annual frequency of the accident may differ among alternatives (i.e., an accident may become more likely as more drums are stored at a site).

Note that the single-drum accident that poses the highest risks to the offsite population may not be the same as the maximum reasonably foreseeable accident for workers (because exposure scenarios and pathways often differ between workers and the other receptors).

D.3.3.5.2 *Storage Facility Accidents*

Potential storage facility HW accidents include (1) a facility fire that engulfs a significant fraction of the containers in storage, releasing some or all of these contaminants: 2A, 2B, 2C, 2D, 5E, and 5F (see Table D.3.3–13); (2) an earthquake that ruptures a significant number of drums, releasing some or all of these contaminants: 1A, 1B, 1C, 1D, 4E, 4F, and 4G in Table D.3.3–13; and (3) the crash of a large aircraft (at Hanford, INEL, and SRS) or small aircraft (at LANL and ORR) resulting in a fire that burns a significant portion of the storage drums releasing some or all of these contaminants: 2A, 2B, 2C, 2D, 3A, 3D, 5E, and 5F in Table D.3.3–13. Earthquake-related storage accidents were postulated for Hanford and LANL only in Regionalized 1 and for INEL and ORR in Regionalized 2.

Table D.3.3–13. Summary of Single-Drum Accident Scenarios for HW

Scenario	Accident Category	Toxic Gases Released
Spill	1A	Ammonia
	1B	Hydrogen chloride
	1C	Hydrogen fluoride
	1D	Sulfur oxides
Spill and fire	2A	Polyaromatic hydrocarbon soot, unburnt hydrocarbons and carbon monoxide
	2B	Hydrogen fluoride
	2C	Cyanide
	2D	Mercury vapor
Spill, fire, and gas cylinder explosion	3A	Ammonia
Fire and gas cylinder breach	3B	Ammonia
Fire and gas cylinder breach	3C	Ammonia
Spill and explosion	3D	Ammonia
Fire and explosion	3E	Ammonia
Spill	4A	Ammonia
	4B	Hydrogen chloride
	4C	Hydrogen fluoride
	4D	Sulfur oxides
	4E	Acetic acid
	4F	Carbon disulfide
	4G	1,1,1-Trichloroethane
Fire	5A	Polyaromatic hydrocarbon soot and unburnt hydrocarbons
	5B	Hydrogen fluoride
	5C	Cyanide
	5D	Mercury vapor
	5E	Cadmium fumes
	5F	Dust from burnt and unburnt potassium and sodium dichromate salts
Spill, fire, and gas cylinder explosion	6A	Ammonia
Fire and gas cylinder breach	6B	Ammonia
Fire and gas cylinder breach	6C	Ammonia
Spill and explosion	6D	Ammonia
Fire and gas cylinder explosion	6E	Ammonia

D.3.3.5.3 *Treatment Facility Accidents*

The treatment facility accidents analyzed for HW include (1) an incinerator explosion and resulting fire; (2) an earthquake with subsequent fire; and (3) a large or small aircraft impact (assuming the same scenarios as for the storage facility accidents) and resulting fire. All three types of incinerator accidents involve a fire and a release of some or all of these contaminants: 2A, 2B, 2C, 2D, 5E, and 5F.

D.3.3.6 Special Assumptions and Considerations Used in the HW Accident Analysis

The source terms for the HW accidents include the period of time over which a particular accident release occurs. For assessing risks to offsite and noninvolved worker receptors from single-drum and facilitywide accidents, all releases have been averaged for a 1-h release (i.e., for contaminant releases greater than 60 min in duration, the amount released was scaled to reflect a 60-min release; for contaminant releases of less than 60 min in duration, the total amount of contaminant is assumed to be released in 60 min).

In estimating the risks to the offsite and noninvolved worker populations, releases from storage facility accidents are assumed to be ground releases without flow (i.e., releases at ground level); releases from incinerator facility accidents are assumed to be stack releases with flow (i.e., release from the stack of an operating facility).

All storage accidents are assumed to involve six workers, the average number of workers needed to place waste in storage facilities (EG&G, 1992). For treatment (incineration) accidents, one shift of workers is assumed to be present in the facility when the accident occurs; shift size varies with the waste processing rate. For HW, from one to five workers are present during treatment accidents (see Table D.3.3–20 in Section D.3.3.7) (EG&G, 1992).

All releases from storage accidents are assumed to take place outside at an outdoor storage facility. A 5-min worker exposure duration is assumed for outdoor exposures to accidents that are readily visually detectable (fires, explosions, spills plus fire, etc.). For spills alone (which may not be noticed as quickly), a 10-min exposure period is assumed. Outdoor worker exposure concentrations were calculated using the INEXPLC

model for close-in atmospheric dispersion, explosive releases, and particle deposition (ORNL, 1993), using the following assumptions:

- The worker is standing directly downwind of the release.
- The release height is 0 m (i.e., at ground level).
- The receptor height is 1.5 m (i.e., the height of the person's nose).
- The radius of the source is 1.5 m.
- Receptor distances were varied from 1 m to 25 m at 1-m intervals and concentrations calculated at each interval; an average of these concentrations was used as the exposure concentration.
- Simple gas dispersion with no particle settling takes place.

Incineration accidents are accompanied by releases into an indoor operating gallery where the workers are located. Half the gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. An exposure duration of 1 min is assumed, during which workers avoid any obstructions and leave the scene. Indoor worker exposure concentrations are estimated using a room model with no ventilation.

Cancer potency factors from the EPA Integrated Risk Information System and Health Effects Assessment Summary Tables were used for determining the cancer incidence resulting from accidents that released carcinogenic chemicals. RfCs and lethality concentrations for acute exposure to toxic chemicals are derived from the methodology developed by Hartmann et al. (1994). Cadmium and benzene are considered to be the carcinogens in the HW accident source terms. Cadmium is toxic as well as carcinogenic, so it is incorporated into both the IDLH index and cancer incidence risk for workers. For the offsite and noninvolved worker populations exposed to cadmium, only the risk of cancer incidence is evaluated because no acute RfD is available to calculate a hazard index. The toxicity and slope factors and IDLH values for cadmium dust are used for accident subcategory 5E because no analogous values are available for cadmium fumes.

The chemical surrogates in Table D.3.3–14 are used in the HW accident risk estimates for all receptors. Hazardous waste manifests for the transport of HW were often not explicit as to exact chemical components, giving only general categories. As a result, a more toxic chemical in a general category was chosen as a conservative representative of the entire category.

Table D.3.3–14. Chemical Surrogates Used in Risk Analysis for Potential HW Accidents

Chemical Hypothetically Released in Accident	Surrogate Used in Risk Analysis
Cyanides (hydrogen, potassium, etc.)	Hydrogen cyanide
Dichromate salts (potassium, sodium, etc.)	Potassium dichromate
Polyaromatic hydrocarbon soot and unburnt hydrocarbons	Benzene
Sulfur oxides	Sulfur dioxide

There is an associated estimated annual frequency of occurrence for each accident type (see Section D.2.12.1). However, the probability of occurrence is not taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. The various single drum accidents have estimated annual frequencies of occurrence ranging from "unlikely" (1.0E–04 to 1.0E–02) to "very unlikely"(1.0E–06 to 1.0E–04). The incinerator explosion and fire is considered to be "anticipated" (greater than 1.0E–02); the earthquake causing a storage facility spill or an incinerator fire is considered "unlikely" to "very unlikely," depending on the location of the site; and aircraft impact is regarded as "extremely unlikely" (less than 1.0E–06), depending on site location (see Appendix F).

D.3.3.7 Results Tables for the Risk Analysis of Potential HW Accidents

Table D.3.3–15 shows a summary of the risks to the offsite and waste management worker populations from the most conservative single-drum, single-contaminant releases, by site and alternative. Tables D.3.3–16 through D.3.3–19 present a summary of risks to the offsite, noninvolved worker, and waste management worker populations for treatment and storage facility accidents, by site and alternative. Table D.3.3–20 provides the sizes of the offsite, noninvolved worker, and worker populations at each site.

Table D.3.3–15. Summary of Risks to the Offsite and Waste Management Worker Populations From Potential Single-Drum HW Accidents, by Alternative and Site

Site	Alternative	Receptor and Endpoint							
		Offsite Population		Offsite MEI		Worker Population		Maximally Exposed Worker	
		Accident[a]	CI	Accident	HI	Accident	CI	Accident	IDLH Index
Hanford	Reg. 1	5E (U)[b]	3.2E-04	2D (U)	8.1E-02	5E (U)	2.5E-03	5F (VU)	6.4E+01
INEL	Reg. 1	5E (U)	2.1E-04	2D (U)	5.3E-01	5E (U)	2.5E-03	5F (U)	6.4E+01
LANL	Reg. 1	5E (U)	3.0E-04	2D (U)	9.9E-01	5E (U)	2.5E-03	5F (U)	6.4E+01
ORR	Reg. 1	5E (VU)	5.9E-03	2D (U)	5.8	5E (VU)	2.5E-03	5F (VU)	6.4E+01
SRS	Reg. 1	5E (U)	2.6E-05	2D (U)	8.1E-02	5E (U)	2.5E-03	5F (0)[c]	6.4E+01
INEL	Reg. 2	5E (U)	2.1E-04	2D (U)	5.3E-01	5E (U)	2.5E-03	5F (U)	6.4E+01
ORR	Reg. 2	5E (U)	5.9E-03	2D (U)	5.8	5E (U)	2.5E-03	5F (U)	6.4E+01

Notes: MEI = maximally exposed individual; CI = risk of cancer incidence associated with exposure to chemical carcinogens; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals; Reg.1 = Regionalized Alternative 1; Reg. 2 = Regionalized Alternative 2.

[a] Maximum reasonably foreseeable single-drum accident type.

[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

[c] The annual frequency of this accident occurring at SRS is 0.

Table D.3.3-16. Risks Associated With Potential Facilitywide HW Storage Accidents Under Regionalized Alternative 1, by Accident and Site

Site	Offsite Pop CI	Offsite MEI HI	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Storage Facility Fire						
Hanford (U)[a]	2.8E-03	1.1	1.5E-05	5.6	1.8E-02	9.0E+02
INEL (U)	1.7E-03	1.5	6.8E-03	1.4E+01	2.0E-02	5.1E+02
LANL (U)	8.3E-03	3.1E+01	1.8E-03	4.4E+02	6.6E-02	2.4E+03
ORR (U)	1.8E-02	7.6E+01	2.3E-02	8.4E+02	5.3E-03	6.0E+02
SRS (U)	5.6E-04	1.7	2.8E-03	1.1E+02	5.4E-02	1.3E+03
Large or Small Aircraft Impact and Storage Facility Fire						
Hanford (EU) (large)	2.8E-03	1.2	1.4E-05	6.2	1.8E-02	1.4E+03
INEL (EU) (large)	1.7E-03	1.6	6.9E-03	1.4E+01	2.0E-02	5.3E+02
LANL (EU) (small)	8.3E-03	3.2E+01	1.8E-03	4.5E+02	6.6E-02	2.7E+03
ORR (EU) (small)	1.8E-02	7.7E+01	2.3E-02	8.5E+02	5.3E-03	6.8E+02
SRS (EU) (large)	5.9E-04	1.7	2.8E-03	1.1E+02	5.4E-02	1.3E+03
Earthquake and Resulting Spill of Multiple Storage Containers						
Hanford (VU)	0.0[b]	1.6E-03	0.0[b]	8.5E-03	0.0[b]	1.2
LANL (U)	0.0[b]	2.0E-02	0.0[b]	2.8E-01	0.0[b]	1.2

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).
[b] Zero indicates that no carcinogen is released in accident scenario.

Table D.3.3-17. Risks Associated With Potential Facilitywide HW Storage Accidents Under Regionalized Alternative 2, by Accident and Site

Site	Offsite Pop CI	Offsite MEI HI	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Storage Facility Fire						
INEL (U)[a]	1.2E-02	3.6E+01	4.8E-02	3.2E+02	1.4E-01	5.1E+03
ORR (U)	1.6E-01	2.4E+02	2.1E-01	2.6E+03	6.1E-02	2.2E+03
Large or Small Aircraft Impact With Resulting Fire						
INEL (EU) (large)	1.2E-02	3.7E+01	4.8E-02	3.3E+02	1.4E-01	6.2E+03
ORR (EU) (small)	1.6E-01	2.4E+02	2.1E-01	2.6E+03	6.1E-02	2.3E+03
Earthquake and Resulting Spill of Multiple Storage Containers						
INEL (U)	0.0[b]	1.9E-01	0.0[b]	1.7	0.0[b]	8.0
ORR (U)	0.0[b]	1.1E-01	0.0[b]	1.3	0.0[b]	1.2

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).
[b] Zero indicates that no carcinogen is released in accident scenario.

Table D.3.3-18. Risks Associated With Potential Facilitywide HW Treatment Accidents Under Regionalized Alternative 1, by Accident and Site

Site		Offsite Pop CI	Offsite MEI HI	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Incinerator Explosion and Fire							
Hanford	(A)[a]	1.9E-05	8.0E-02	9.8E-08	4.3E-01	1.0E-06	3.9E+01
INEL	(A)	2.0E-04	0.0[b]	4.7E-04	0.0[b]	2.5E-04	7.9E+01
LANL	(A)	3.1E-04	9.5E-01	6.1E-05	7.3	7.5E-04	1.2E+02
ORR	(A)	5.5E-03	3.5	4.8E-04	3.7	1.0E-03	2.0E+02
SRS	(A)	7.6E-07	8.0E-02	3.4E-06	4.4	5.0E-07	3.9E+01
Large or Small Aircraft Impact With Resulting Fire							
Hanford (large)	(EU)	5.6E-05	1.8E-01	2.9E-07	9.8E-01	3.0E-06	3.6E+02
INEL (large)	(EU)	4.1E-04	8.3E-02	9.4E-04	4.6E-01	5.0E-04	2.3E+02
LANL (small)	(EU)	3.4E-04	1.3	6.6E-05	9.9	7.6E-04	4.8E+02
ORR (small)	(EU)	1.1E-02	6.8	9.7E-04	7.1	2.0E-03	3.2E+02
SRS (large)	(EU)	2.9E-05	8.1E-02	1.3E-04	4.4	5.0E-04	1.2E+02
Earthquake With Resulting Fire							
Hanford	(VU)	3.7E-05	1.0E-01	2.0E-07	5.5E-01	2.0E-06	3.2E+02
INEL	(VU)	2.1E-04	8.3E-02	4.8E-04	4.6E-01	2.5E-04	1.6E+02
LANL	(VU)	3.5E-04	1.0	6.8E-05	7.8	7.8E-04	2.0E+02
ORR	(VU)	1.1E-02	6.8	9.7E-04	7.1	2.0E-03	3.2E+02
SRS	(VU)	2.7E-05	8.1E-02	1.2E-04	4.4	5.0E-04	1.2E+02

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).
[b] Zero indicates that no acute RfD was available for contaminant; cancer incidence only was calculated.

Table D.3.3-19. Risks Associated With Potential Facilitywide HW Treatment Accidents Under Regionalized Alternative 2, by Accident and Site

Site	Offsite Pop CI	Offsite MEI HI	Noninvolved Worker Pop CI	Noninvolved Worker MEI HI	Worker CI	Worker IDLH Index
Incinerator Explosion and Fire						
INEL (A)[a]	2.3E-04	4.9E-01	5.2E-04	2.7	1.3E-03	2.0E+02
ORR (A)	6.0E-03	6.6	5.2E-04	6.9	1.3E-03	1.6E+02
Large or Small Aircraft Impact With Resulting Fire						
INEL (large) (EU)	4.5E-04	1.5	1.0E-03	8.5	2.5E-03	6.4E+02
ORR (small) (EU)	1.2E-02	1.1E+01	1.0E-03	1.1E+01	2.5E-03	5.6E+02
Earthquake With Resulting Fire						
INEL (VU)	8.6E-04	2.1	2.0E-03	1.2E+01	5.0E-03	9.9E+02
ORR (VU)	1.2E-02	1.1E+01	1.0E-03	1.1E+01	2.5E-03	5.6E+02

Notes: CI = risk of cancer incidence associated with exposure to chemical carcinogens; MEI = maximally exposed individual; HI = hazard index associated with exposure to noncarcinogenic, hazardous chemicals.
[a] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.3-20. Size of Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Potential HW Treatment and Storage Accidents, by Site

Site	Offsite Population	Noninvolved Worker Population	Storage Worker Population		Treatment Worker Population	
			Regionalized 1	Regionalized 2	Regionalized 1	Regionalized 2
Hanford	377,645	8,674	6		2	
INEL	153,061	8,451	6	6	1	5
LANL	159,152	11,552	6		3	
ORR	881,652	3,809	6	6	4	5
SRS	620,618	15,996	6		2	

D.3.3.8 Summary of the HW Accident Analysis Results

In general, the accident analyses indicate the same trend as seen in routine waste management operations: as the volume of waste is increased at a site, the risks to the public and workers during treatment and storage increase. In Regionalized Alternative 2, approximately 80% of DOE-generated HW is treated at two sites, while treatment of 50% of DOE HW is distributed across five sites in Regionalized 1. Accordingly, the accident risks to all receptors at INEL and ORR in Regionalized 2 tend to be higher than the Regionalized 1 risks at these sites by roughly 1 order of magnitude for storage accidents and by only a slight margin for treatment accidents.

The single-drum storage accidents with the greatest risks to the offsite population and MEI involve releases of cadmium and mercury vapor. The single-drum accidents with the greatest risks to workers involve releases of cadmium and dichromate salts. The facility-wide storage accidents that would produce the highest risks to all receptors are the storage facility fire and the crash of an aircraft into a storage facility followed by fire. However, the storage facility fire is considered "unlikely" (1.0E–04 to 1.0E–02), whereas the aircraft impact scenario is designated "extremely unlikely" (less than 1.0E–06). For treatment facility accidents, consequences are generally similar among accident types at a given site; however, the incinerator explosion is considered much more likely (greater than 1.0E–02 or "anticipated") than other scenarios. The most common controlling contaminants in HW accident scenarios are cadmium and mercury vapor. The highest-risk sites are usually INEL, ORR, and LANL.

D.3.3.8.1 *Risks to the Offsite Population From Accidents During Storage*

Single-Drum Accidents. For the offsite population at each site, the highest cancer incidence risks are associated with a forklift accident resulting in a spill and fire involving a release of cadmium fumes (5E) (see Table D.3.3–15). These risks of cancer incidence range from 2.6E–05 to 5.9E–03 in Regionalized 1 and from 2.1E–04 to 5.9E–03 in Regionalized 2. The highest cancer incidence is at ORR in both Regionalized 1 and 2 (5.9E–03 occurrences affecting a population of 881,652). The next highest risks of cancer incidence are at Hanford and LANL in Regionalized 1 and at INEL in both alternatives (3.2E–04, 3.0E–04, and 2.1E–04, respectively). The lowest cancer incidence risks are at SRS in Regionalized 1 (2.6E–05). The consequences at a site of the maximum reasonably foreseeable single-drum accident (if it occurred) do not differ between alternatives. However, the estimated annual frequency of the accident

increases almost 2 orders of magnitude at ORR from "very unlikely" (1.0E–06 to 1.0E–04) to "unlikely" (1.0E–04 to 1.0E–02) in Regionalized 2. The accident is considered "unlikely" at all other sites in both alternatives.

Storage Facility Accidents. For the offsite population, storage facility fires and aircraft impacts with subsequent fires would pose about the same risks of cancer incidence if they occurred at a site (see Tables D.3.3–16 and D.3.3–17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" [1.0E–04 to 1.0E–02] versus "extremely unlikely" [less than 1.0E–06], respectively). In general, the risks at each site are 1 order of magnitude higher in Regionalized 2 than in Regionalized 1. This is because approximately 80% of DOE-generated HW is treated at two sites in Regionalized 2 while treatment of 50% of DOE HW is distributed across five sites in Regionalized 1.

The highest cancer incidence risks from a storage facility fire or an airplane impact affecting a storage facility are at ORR in Regionalized 1 and 2 (1.8E–02 and 1.6E–01, respectively, in an affected population of 881,652), INEL in Regionalized 2 (1.2E–02 in a population of 153,061), and LANL in Regionalized 1 (8.3E–03 in a population of 159,152) (ANL, 1996f). At all three sites, the controlling contaminant is cadmium.

D.3.3.8.2 *Risks to the Offsite Population From Accidents During Treatment*

The risks of cancer incidence to the offsite population from facility-wide accidents during incineration range from 7.6E–07 to 1.1E–02 in Regionalized 1 and from 2.3E–04 to 1.2E–02 in Regionalized 2. In Regionalized 1, cancer incidence risks to the offsite population are similar among accident types (incinerator explosion, aircraft crash into a incinerator facility, and earthquake and fire affecting an incinerator facility) at a given site, differing by only a factor of three or less in most instances. One exception is the incinerator explosion scenario at SRS, which results in a cancer incidence to the offsite population (7.6E–07) that is more than 1 order of magnitude lower than other accident types at SRS. (This is because the carcinogen cadmium is released in the other accident types, but not in the incinerator explosion scenario.) Cancer incidence risks to the offsite population are also similar among accident types at INEL and ORR in Regionalized 2, differing by less than a factor of four. However, in both alternatives, the estimated annual

frequency associated with each of the three treatment facility accident scenarios is different: the incinerator explosion is considered "anticipated" (estimated annual frequency greater than 1E–02); the aircraft impact scenario is "extremely unlikely" (less than 1E–06); and the earthquake scenario is "very unlikely" (1E–06 to 1E–04).

ORR is the highest-risk site for all accident types and alternatives. The highest cancer incidence risks are for the aircraft impact or the earthquake at ORR in both alternatives (1.1E–02 in Regionalized 1 and 1.2E–02 in Regionalized 2). The driving contaminant at ORR for these accident types is cadmium.

D.3.3.8.3 *Risks to the Noninvolved Worker Population From Accidents During Storage*

The risk of cancer incidence in the noninvolved worker population due to accident-related releases follows a similar pattern to that for the offsite population. At each site, storage facility fires and aircraft impacts with subsequent fires pose about the same risks of cancer incidence (see Tables D.3.3–16 and D.3.3–17); however, facility fires are projected to occur more frequently than airplane crashes ("unlikely" versus "extremely unlikely," respectively). Accident risks in Regionalized 2 are approximately 1 order of magnitude higher than those in Regionalized 1 for each site. This is due to a greater number of breached containers involved in the Regionalized 2 accident scenarios. Cancer incidence due to storage accidents ranges from 1.4E–05 to 2.3E–02 in Regionalized 1 and from 4.8E–02 to 2.1E–01 in Regionalized 2.

For the airplane impact affecting a storage facility and the storage facility fire, the highest cancer incidence risks are at ORR in Regionalized 1 and 2 (2.3E–02 and 2.1E–01, respectively, in an affected population of 3,809). The next highest cancer incidence risks are from an airplane impact or storage facility fire at INEL (approximately 7.0E–03 in Regionalized 1 and 4.8E–02 in Regionalized 2). Cadmium is the controlling contaminant at both sites. The site with the lowest cancer incidence risks to noninvolved workers from storage accidents is Hanford in Regionalized 1.

D.3.3.8.4 *Risks to the Noninvolved Worker Population From Accidents During Treatment*

The risks of cancer incidence to the noninvolved worker population from facility-wide accidents during incineration range from 9.8E–08 to 9.7E–04 in Regionalized 1 and from 5.2E–04 to 2.0E–03 in

Regionalized 2. In both alternatives, cancer incidence risks to noninvolved workers are similar among accident types at a given site, differing by only a factor of three or less in most instances. One exception is the incinerator explosion scenario at SRS which results in a cancer incidence (3.4E-06) that is nearly 2 orders of magnitude lower than other accident types at SRS. (This is because the carcinogen cadmium is released in the other accident types, but not in the incinerator explosion scenario.)

The highest site risks of cancer incidence are at ORR and INEL for all accident types. Cancer incidence risks to noninvolved workers at INEL range from 4.7E-04 to 9.4E-04 in Regionalized 1 and from 5.2E-04 to 2.0E-03 in Regionalized 2. ORR cancer incidence risks are very similar to those at INEL, ranging from 4.8E-04 to 9.7E-04 in Regionalized 1 and from 5.2E-04 to 1.0E-03 in Regionalized 2. The controlling contaminant is cadmium at both sites.

D.3.3.8.5 *Risks to the Maximally Exposed Offsite Individual From Single-Drum Accidents*

The maximum reasonably foreseeable single-drum accident involving the release of a noncarcinogenic chemical is a forklift accident that results in a spill and fire with release of mercury vapor (2D) (see Table D.3.3-15). The highest hazard index is at ORR in both alternatives (5.8), indicating an increased likelihood of adverse health effects. The next highest hazard index resulting from this accident type is 9.9E-01 at LANL in Regionalized 1; this value approaches the threshold value of 1.0 beyond which adverse health effects become more likely. All other hazard indices are below 1.0. The estimated annual frequency of occurrence for this accident type is "unlikely" for all sites and alternatives.

D.3.3.8.6 *Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From Storage Facility Accidents*

Accidents During Storage. The highest hazard indices for the offsite MEI from an airplane impact affecting a storage facility or a storage facility fire are at ORR in Regionalized 1 and 2 (approximately 7.7E+01 and 2.4E+02, respectively); INEL in Regionalized 2 (approximately 3.7E+01); and LANL in Regionalized 1 (approximately 3.2E+01). The same trend holds true for the noninvolved worker MEI. At all three sites the controlling contaminant is mercury vapor.

Hazard indices associated with earthquake scenarios that affect storage facilities are usually less than 1.0 with the exception of the noninvolved worker MEI at ORR and INEL in Regionalized 2 (1.3 and 1.7, respectively). The hazard index from an earthquake-related accident is generally 2 to 3 orders of magnitude less than those associated with other storage facility accidents at the same site. In terms of annual accident frequency, earthquake and facility fire scenarios are considered "unlikely" (with the exception of the earthquake scenario at Hanford in Regionalized 1 which is considered "very unlikely"), while aircraft impacts are "extremely unlikely" to happen.

Accidents During Treatment. The highest hazard indices to the offsite MEI for all accident types are at ORR in Regionalized 1 and 2 (ranging from 3.5 to 1.1E+01); the aircraft impact and earthquake scenarios at INEL in Regionalized 2 (1.5 and 2.1, respectively); and the aircraft impact and earthquake scenarios at LANL in Regionalized 1 (1.3 and 1.0, respectively). The controlling contaminant at these sites is mercury vapor. The highest hazard indices to the noninvolved worker MEI are for all accident types at ORR in both alternatives (ranging from 3.7 to 1.1E+01); LANL in Regionalized 1 (ranging from 7.3 to 9.9); SRS in Regionalized 1 (4.4 for all accident types); and INEL in Regionalized 2 (ranging from 2.7 to 12). Each of these accidents, were it to occur, would result in exposures that might lead to adverse health effects to the MEIs. Recall, however, that the incinerator explosions are considered "anticipated," while the earthquake and aircraft impact scenarios are considered "very unlikely" and "extremely unlikely," respectively.

D.3.3.8.7 *Risks to Waste Management Workers From Storage and Treatment Facility Accidents*

Accidents During Storage. The single-drum accident scenario resulting in the highest cancer incidence risk to workers (2.5E-03) is 5E, the forklift accident leading to a spill and fire with release of cadmium fumes (see Table D.3.3-13). The single-drum accident with the greatest risks to workers and involving the release of a noncarcinogen is 5F, a forklift accident resulting in a spill and fire with a release of dust from burnt and unburnt dichromate salts (analyzed as potassium dichromate). The IDLH index associated with this accident is 6.4E+01, which is 64 times the exposure concentration that could cause irreversible health effects if exposure were to last as long as 30 min. However, the accident scenario assumes a much shorter exposure duration, which could reduce the severity of health effects. For each site, the consequences of the maximum reasonably foreseeable single-drum accidents for workers are the same across alternatives. However, the estimated annual frequency of accident types 5E and 5F increases at ORR from "very

unlikely" in Regionalized 1 to "unlikely" in Regionalized 2. Note that the estimated annual frequency of 5F is zero (i.e., 5F is assumed not to occur) at SRS in Regionalized 1.

Storage facility fires and aircraft impacts with subsequent fires would pose very similar risks of cancer incidence and IDLH indices were they to occur at an site (see Tables D.3.3–16 and D.3.3–17). However, facility fires are projected to occur more frequently than airplane crashes ("unlikely" versus "extremely unlikely," respectively). Both cancer incidence risk and IDLH index increase by about 1 order of magnitude at INEL and ORR from Regionalized 1 to Regionalized 2 due to centralization of waste loads. The highest risk of cancer incidence is associated with the storage facility fire or aircraft crash at INEL in Regionalized 2 (1.4E–01 for each accident). The highest IDLH indices are also for the storage facility fire and aircraft crash at INEL in Regionalized 2 (5.1E+03 and 6.2E+03, respectively). These IDLH indices indicate that, were one of these accidents to occur, contaminant concentrations would greatly exceed the level considered immediately dangerous to life and health for exposures of 30 min. However, the accident scenarios assume a much shorter exposure duration, which could reduce the severity of health effects. The controlling contaminants at INEL are cadmium and mercury vapor.

Earthquake-related accidents result in IDLH indices greater than 1.0, but 2 to 3 orders of magnitude less than those resulting from other storage facility accidents. The highest IDLH index for earthquake-related releases from storage is also at INEL in Regionalized 2 (8.0). No carcinogens are assumed to be released in earthquake scenarios.

Accidents During Treatment. In both alternatives, cancer incidence risks to workers are similar among treatment accident types at a given site. However, similar to the trend for offsite and noninvolved worker populations, there is one exception: the incinerator explosion at SRS in Regionalized 1 results in a cancer incidence risk to workers of 5.0E–07; this is 3 orders of magnitude lower than other treatment facility accidents at SRS. As previously discussed, this is because there is no cadmium in the source term for the incinerator explosion. The highest site risks are for all accident types at ORR in both alternatives (ranging from 1.0E–03 to 2.0E–03) and INEL in Regionalized 2 (ranging from 1.3E–03 to 5.0E–03). The controlling contaminant is cadmium at both sites.

IDLH indices are similar among accident types at a given site in both alternatives. One notable exception is the incinerator explosion at Hanford in Regionalized 1, which results in an IDLH index approximately 1 order of magnitude lower than for other accident types. This is primarily because there is no cyanide in

the incinerator explosion source term (in contrast to the other accident types), since cyanide is converted to less toxic cyanates (ANL, 1996f). All IDLH indices associated with treatment facility accidents are greater than 1.0 by 1 to 3 orders of magnitude, indicating exposures to workers that could lead to irreversible health effects.

D.3.4 TRANSURANIC WASTE

DOE Order 5820.2A defines transuranic waste (TRUW) as, "[w]ithout regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years, and concentrations greater than 100 nCi/g [nanocuries per gram] at the time of assay" (DOE, 1988). This lower activity limit is interpreted as being per gram of actual waste matrix, excluding the weight of added external shielding, liners, or packaging. By definition, TRUW includes neptunium, plutonium, americium, curium, and californium. DOE Order 5820.2A also provides for the management of some other alpha-contaminated wastes as TRUW, such as wastes containing uranium-233 and radium-226, as necessary. In this appendix the term "TRUW" refers to all materials meeting the DOE definition including TRUW that contain hazardous constituents regulated by the Resource Conservation and Recovery Act (RCRA). The principal focus of the PEIS is on TRUW generated since 1970, which has been packaged and retrievably stored in various trench, pit, vault, and pad configurations. (TRUW generated before 1970 was buried onsite in shallow landfills and may be addressed through environmental restoration activities.)

TRUW is generated primarily in research and development, weapons manufacturing, and plutonium recovery; some TRUW is also retrieved during environmental restoration and decontamination and decommissioning. DOE sites that generate or store TRUW (note that the abbreviations given here are used throughout this appendix) include the following:

- Argonne National Laboratory-East (ANL-E), Argonne, Illinois
- Argonne National Laboratory-West (ANL-W), Idaho Falls, Idaho
- Energy Technology Engineering Center (ETEC), Canoga Park, California
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California

- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories-New Mexico (SNL-NM), Albuquerque, New Mexico
- Sandia National Laboratories-California (SNL-CA), Livermore, California
- Savannah River Site (SRS), Aiken, South Carolina
- University of Missouri (Columbia) (UofMO), Columbia, Missouri
- West Valley Demonstration Project (WVDP), West Valley, New York
- Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico

This list includes the 12 major sites considered for TRUW management described in Section 8.4.1 of Volume I. Treatment risks were also estimated separately later in this section in Tables D.3.4–12 through D.3.4–17 for several other sites in addition to the 12 major TRUW management sites. Note that for the purposes of this risk analysis, the waste loads from three smaller generators were added to the inventories of larger generators. Specifically, the ITRI waste load was combined with the SNL-NM inventory, the ANL-W waste load was added to the INEL inventory, and the SNL-CA waste load was combined with the LLNL inventory. Also, source terms were not available for ETEC, UofMO, and WVDP, so risks at these installations were not evaluated (ANL, 1996b). Treatment risks at LBL and Mound are contained in the programwide risk tables (Tables D.3.4–6 through D.3.4–11) presented in this section of the WM PEIS and in the alternative summary risk tables presented in Section 8.4 of Volume I.

Most TRUW is solid waste (such as contaminated tools, machine parts, protective clothing, and laboratory glassware) but some is in liquid or sludge forms. Perhaps 50 to 60 % of the DOE inventory of TRUW is mixed waste, containing both radioactive and hazardous constituents regulated under RCRA. Examples of this mixed waste include sludges contaminated with spent solvents, debris contaminated with solvents and radionuclides, and discarded contaminated lead shielding. Depending on its chemical and physical properties, TRUW can be grouped into waste stream categories, such as aqueous liquids, organic liquids, solid process residues, soils, or debris, according to the type of treatment needed.

Packaged TRUW with a surface dose rate of less than 200 mrem/h is categorized as contact-handled TRUW (CH-TRUW). Packaged TRUW with a surface dose rate greater than 200 mrem/h emits sufficient penetrating beta, gamma, or neutron radiation to require remote handling, and is classified as remote-handled TRUW (RH-TRUW). The handling category determines the level of protective shielding needed to store and process the waste safely. The distinction between CH-TRUW and RH-TRUW is maintained in the human health risk analysis for both routine operations and accidents. Therefore, the results for CH-TRUW are presented separately from the results for RH-TRUW.

The DOE Waste Isolation Pilot Plant (WIPP), located near Carlsbad, New Mexico, has been identified as the permanent disposal site for DOE-generated TRUW. To ensure that TRUW can be disposed of safely at WIPP, DOE has developed a set of waste acceptance criteria (referred to as "WIPP-WAC" in the risk analysis tables) that waste generators and treatment and storage sites must meet before shipping TRUW to WIPP. These waste acceptance criteria were taken into account in developing the PEIS alternatives. However, because the final WIPP disposal criteria will likely be more stringent than current criteria, two additional treatment standards were evaluated in this analysis. The first of these was treatment to an intermediate waste form that generates less gas from the degradation of organic chemicals and corrodible metals than is mandated by current WIPP waste acceptance criteria. This is accomplished mainly by shredding and grouting the wastes and packaging them in containers that are not expected to release significant amounts of gases when disposed of at WIPP. The second was treatment to meet RCRA land disposal restrictions (LDRs) as promulgated in 1986 in Title 40, Chapter 268 of the Code of Federal Regulations. This is the most extensive of the three treatment standards; wastes are incinerated to destroy most of the hazardous organic chemical components. Inorganic components such as metals remain in ash after incineration. Small quantities of radioactive or hazardous constituents would be released into the environment from treatment facilities considered in this study. On the basis of the releases, human health risks were evaluated; the results are presented in this appendix.

Chapters 3 and 8 of the PEIS and the TRUW technical report (ANL, 1996b) provide more detailed information on this waste, including TRUW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, and the process for developing PEIS TRUW alternatives.

D.3.4.1 Summary of CH-TRUW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing the various CH-TRUW analysis alternatives are discussed rigorously in the main body of the PEIS.

- The No Action Alternative demonstrates the baseline risks of newly generated CH-TRUW packaging, certification, and indefinite interim storage at all generator sites. Treatment is not considered, and it is assumed that TRUW will not be disposed of at WIPP, although it will be prepared as though it were going to WIPP. The No Action Alternative does not assess the health risks, environmental impacts, or costs of removing TRUW from retrievable storage and packaging it.
- The Decentralized Alternative presents the risks of treating wastes to WIPP waste acceptance criteria and storing them at 10 sites.
- In Regionalized Alternative 1, CH-TRUW is consolidated, treated to minimize gas generation, and stored at five sites.
- In Regionalized Alternatives 2 and 3, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at five and three sites, respectively.
- In the Centralized Alternative, CH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at one site.

In Regionalized 1 and 2, consolidation, treatment, and storage take place at the same five sites. Comparison of these alternatives makes it possible to contrast the risks of treatment to minimize gas generation versus treatment to meet RCRA LDRs. Comparison of Regionalized 2, 3, and the Centralized Alternative demonstrates the differences in risks when the same treatment method is used but treatment and storage are performed at five, three, and one site(s), respectively.

Table D.3.4–1 presents the overall treatment and storage schemes for these six alternatives. Table D.3.4–2 shows which sites ship their wastes to regionalized or centralized consolidation sites for treatment and storage.

Table D.3.4–1. PEIS Alternatives for CH-TRUW

Alternative	ANL-E	ETEC[a]	Hanford	INEL[b]	LANL	LBL	LLNL[c]	Mound	NTS	ORR	PGDP	RFETS	SNL-NM[d]	SRS	UofMO[a]	WVDP[a]	WIPP
No Action Alternative	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	
No treatment/store at 16	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	
Decentralized Alternative	T		T	T	T		T	T	T	T		T		T			
Treat to WIPP-WAC/store at 10	S		S	S	S		S	S	S	S		S		S			
Regionalized Alternative 1			T	T	T							T		T			
Treat to reduce gas/store at 5			S	S	S							S		S			
Regionalized Alternative 2			T	T	T							T		T			
Treat to LDRs/store at 5			S	S	S							S		S			
Regionalized Alternative 3			T	T										T			
Treat to LDRs/store at 3			S	S										S			
Centralized Alternative																	T
Treat to LDRs/store at 1																	S

Notes: T = treatment site. S = storage site.
[a] Data for ETEC, UofMO, and WVDP were not available so risks at these sites were not evaluated.
[b] Includes CH-TRUW from ANL-W.
[c] Includes CH-TRUW from SNL-CA.
[d] Includes CH-TRUW from ITRI.

Table D.3.4–2. PEIS Consolidation and Treatment Strategies for CH-TRUW

Alternative	Origin	Treatment and Storage Destination
No Action Alternative No treatment; store at 16 sites	All sites	Generators store own waste
Decentralized Alternative Treat to WIPP-WAC and store at 10 sites	ANL-E Hanford, LBL INEL/ANL-W[a] LANL, SNL-NM/ITRI[a] LLNL/SNL-CA[a] Mound, WVDP[b] NTS, ETEC[c] ORR, PGDP, UofMO[c] RFETS SRS	ANL-E Hanford INEL LANL LLNL Mound NTS ORR RFETS SRS
Regionalized Alternative 1 Treat to minimize gas generation and store at 5 sites	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, NTS LANL, SNL-NM/ITRI RFETS SRS, ANL-E, Mound, ORR, PGDP, UofMO, WVDP	Hanford INEL LANL RFETS SRS
Regionalized Alternative 2 Treat to RCRA LDRs and store at 5 sites	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, NTS LANL, SNL-NM/ITRI RFETS SRS, ANL-E, Mound, ORR, PGDP, UofMO, WVDP	Hanford INEL LANL RFETS SRS
Regionalized Alternative 3 Treat to RCRA LDRs and store at 3 sites	Hanford, LBL, LLNL/SNL-CA INEL/ANL-W, ETEC, LANL, NTS, RFETS, SNL-NM/ITRI SRS, ANL-E, Mound, ORR, PGDP, UofMO, WVDP	Hanford INEL SRS
Centralized Alternative Treat to RCRA LDRs and store at WIPP	All sites	WIPP

[a] For the purpose of the human health risk analysis, the ANL-W waste load is added to the INEL inventory, the ITRI waste load is added to the SNL-NM inventory, and the SNL-CA waste load is added to the LLNL inventory.
[b] Source terms for WVDP were not available because the wastes at WVDP were special types that were not analyzed (see Section 8.2.1.1 of the WM PEIS). The new data in Appendix I shows some solid process residues and debris wastes, but in relatively small increments.
[c] Source terms for ETEC and UofMO were not evaluated (see Section 8.1.2 of the WM PEIS).

D.3.4.2 Special Assumptions and Considerations Used in the TRUW Risk Analysis

For all alternatives except the No Action Alternative (for CH-TRUW and RH-TRUW), it is assumed that new facilities will be operational in the year 2003. All current inventory, retrievably stored waste, and waste generated between 1993 to 2013 will be treated from approximately 2003 to 2013. Waste generated after 2013 will be treated as necessary (ANL, 1996b). Therefore, all alternatives except No Action were evaluated to estimate human health risks for a 10-year period of treatment and storage, while No Action was evaluated for a 20-year period. Disposal risks were not estimated for TRUW since it is assumed that all TRUW will be disposed of at WIPP.

It is assumed that WIPP will accept TRUW for disposal from 1998 to 2018. The acceptance rate for waste will average 7,080 m^3/year (250,000 ft^3/year) for 20 years. Because WIPP waste acceptance criteria may change over time, the human health risk assessment was performed for treatment to three increasingly stringent standards to obtain a clearer picture of the full range of potential impacts, (current WIPP waste acceptance criteria, treatment for reduced gas generation, and RCRA LDRs).

In the No Action Alternative, wastes are retrieved where necessary, packaged, certified for shipment to WIPP, and placed in interim storage. There is no treatment of waste other than packaging, but health risks to public receptors and WM workers are assessed for retrieval and packaging operations. Retrieval potentially poses exposure risk due to emissions from corroding waste containers. Therefore, contaminant emissions during both retrieval and packaging were considered as part of routine waste management for TRUW.

Waste containers were assumed to be 55-gal drums for CH-TRUW; 6-in.-wall concrete casks for RH-TRUW; and Transuranic Package Transporter-II (TRUPACT II) containers for packaging wastes to be shipped to WIPP.

A hazard index is reported for the noninvolved worker MEI and offsite MEI, while an exposure index is reported for workers. The HI reflects the highest exposure of the noninvolved worker MEI and offsite MEI to noncarcinogenic, hazardous chemicals. The EI indicates the analogous exposure to an individual FTE.

Staffing requirements, expressed as FTEs, were estimated for the TRUW module for polymer solidification using the FTE data for grout solidification; and for the TRUW module for wet-air oxidation using the FTE

data for wet-air oxidation of alpha-contaminated LLW and LLMW. For more information on the treatment modules, see ORNL (1995b).

D.3.4.3 Results Tables for the CH-TRUW Human Health Risk Analysis

This section contains the results tables for the CH-TRUW human health risk analysis. A discussion of the results is presented in Section D.3.4.4. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.4–3 presents an overview, by alternative, of the *total*, programwide risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers. This table provides the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to CH-TRUW over the next 50 years if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.4–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.4–5 summarizes the risks to the noninvolved worker MEI and offsite MEI for each CH-TRUW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of cancer or develop cancer from radionuclide or chemical exposure, and indicators of the likelihood of suffering adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.4–6 through D.3.4–11 show the programwide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.4–12 through D.3.4–17 present offsite and worker population risks for each installation, by alternative.
- Table D.3.4–18 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population, by site and alternative.

Table D.3.4-3. Summary of Programwide Risks Associated With Routine Management of CH-TRUW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF	CI	CF	CI	CF	CI	C&OF
No Action Alternative	3.5E-05	1.2E-04	3.1E-06	1.1E-05	1.0E-01	3.4E-01	2.5E-01
Decentralized Alternative	1.6E-04	5.5E-04	1.4E-05	5.0E-05	6.1E-01	2.1	2.0
Regionalized Alternative 1	2.6E-04	8.6E-04	2.4E-05	7.9E-05	6.2E-01	2.2	2.3
Regionalized Alternative 2	8.7E-01	2.8	6.8E-02	2.9E-01	5.8E-01	2.0	3.6
Regionalized Alternative 3	1.7E-01	6.5E-01	1.8E-02	7.8E-02	6.3E-01	2.2	2.9
Centralized Alternative	2.6E-01	8.9E-01	2.1E-02	7.2E-02	7.0E-01	2.5	1.6

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides and carcinogenic chemicals; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.4-4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of CH-TRUW, by Alternative

Alternative	Offsite	Noninvolved Worker	WM Worker
No Action	27,716,666	70,681	1,696
Decentralized	28,643,318	92,462	6,485
Regionalized 1	27,716,666	88,653	8,366
Regionalized 2	27,716,666	88,653	14,047
Regionalized 3	27,716,666	88,653	11,469
Centralized	27,861,555	89,713	8,238

Table D.3.4-5. Summary of Programwide Risks Associated With Routine Management of CH-TRUW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative

Alternative	Offsite MEI				Noninvolved Worker MEI			
	CF	Rad CI	Chem CI	HI	CF	Rad CI	Chem CI	HI
No Action	4.4E-10	1.3E-09	3.1E-13	2.6E-11	2.0E-09	6.9E-09	2.7E-10	1.2E-11
Decentralized	5.7E-09	1.9E-08	2.8E-12	1.6E-10	6.8E-09	2.3E-08	8.9E-12	1.4E-09
Regionalized 1	6.9E-09	2.3E-08	4.8E-12	2.2E-10	1.3E-08	4.3E-08	1.5E-11	2.5E-09
Regionalized 2	6.7E-05	2.3E-04	4.8E-12	1.1E-08	4.4E-05	1.5E-04	1.5E-11	2.8E-08
Regionalized 3	5.1E-06	1.7E-05	4.8E-12	7.9E-10	1.4E-05	4.8E-05	1.5E-11	6.3E-09
Centralized	6.9E-05	2.3E-04	2.1E-13	4.9E-11	8.8E-05	2.8E-04	1.3E-12	3.0E-10

Notes: CF = cancer fatality associated with exposure to radionuclides; Rad CI = cancer incidence associated with exposure to radionuclides; Chem CI = cancer incidence associated with exposure to carcinogenic chemicals; HI = hazard index associated with exposure to noncarcinogenic, toxic chemicals.

Table D.3.4-6. Programwide Risks Associated With Managing CH-TRUW Under the No Action Alternative

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	6.3E-03			
	Cancer fatalities	3.1E-06			
	Cancer incidence	1.1E-05	3.4E-09		
	Genetic effects	6.3E-07			
Noninvolved worker MEI	Dose (rem)	4.1E-06			
	Cancer fatalities	2.0E-09			
	Cancer incidence	6.9E-09	2.7E-10		
	Genetic effects	4.1E-10			
	Hazard index			1.2E-11	
Offsite population	Dose (person-rem)	7.0E-02			
	Cancer fatalities	3.5E-05			
	Cancer incidence	1.2E-04	1.4E-08		
	Genetic effects	7.0E-06			
Offsite MEI	Dose (rem)	8.7E-07			
	Cancer fatalities	4.4E-10			
	Cancer incidence	1.5E-09	3.1E-13		
	Genetic effects	8.7E-11			
	Hazard index			2.6E-11	
WM workers	Dose (FTE-rem)	2.5E+02			
	Cancer fatalities	1.0E-01			
	Cancer incidence	3.4E-01	2.8E-07		
	Genetic effects	1.5E-02			
	Exposure index			2.1E-06	
	Construction fatalities				1.1E-01
	Construction injuries				4.2E-01
	Operation fatalities				1.4E-01
	Operation injuries				9.1E-01

Table D.3.4-7. Programwide Risks Associated With Managing CH-TRUW Under the Decentralized Alternative

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	3.0E-02			
	Cancer fatalities	1.4E-05			
	Cancer incidence	5.0E-05	3.4E-08		
	Genetic effects	3.0E-06			
Noninvolved worker MEI	Dose (rem)	1.4E-05			
	Cancer fatalities	6.8E-09			
	Cancer incidence	2.3E-08	8.9E-12		
	Genetic effects	1.4E-09			
	Hazard index			1.4E-09	
Offsite population	Dose (person-rem)	3.2E-01			
	Cancer fatalities	1.6E-04			
	Cancer incidence	5.5E-04	1.3E-07		
	Genetic effects	3.2E-05			
Offsite MEI	Dose (rem)	1.1E-03			
	Cancer fatalities	5.7E-09			
	Cancer incidence	1.9E-08	2.8E-12		
	Genetic effects	1.1E-09			
	Hazard index	1.5E-10		1.5E-10	
WM workers	Dose (FTE-rem)	1.5E+03			
	Cancer fatalities	6.1E-01			
	Cancer incidence	2.1	9.8E-06		
	Genetic effects	9.1E-02			
	Exposure index			3.0E-05	
	Construction fatalities				1.3
	Construction injuries				5.0E+02
	Operation fatalities				6.9E-01
	Operation injuries				5.3E+02

Table D.3.4-8. Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 1

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	4.6E-02			
	Cancer fatalities	2.4E-05			
	Cancer incidence	7.9E-05	5.6E-08		
	Genetic effects	4.6E-06			
Noninvolved worker MEI	Dose (rem)	2.5E-05			
	Cancer fatalities	1.3E-08			
	Cancer incidence	4.3E-08	1.5E-11		
	Genetic effects	2.5E-09			
	Hazard index			2.5E-09	
Offsite population	Dose (person-rem)	5.1E-01			
	Cancer fatalities	2.6E-04			
	Cancer incidence	8.6E-04	2.3E-07		
	Genetic effects	5.1E-05			
Offsite MEI	Dose (rem)	1.4E-05			
	Cancer fatalities	6.9E-09			
	Cancer incidence	2.3E-08	4.8E-12		
	Genetic effects	1.4E-09			
	Hazard index			2.2E-10	
WM workers	Dose (FTE-rem)	1.6E+03			
	Cancer fatalities	6.2E-01			
	Cancer incidence	2.2	1.8E-05		
	Genetic effects	9.2E-02			
	Exposure index			2.4E-05	
	Construction fatalities				1.5
	Construction injuries				6.2E+02
	Operation fatalities				8.1E-01
	Operation injuries				5.9E+02

Table D.3.4-9. Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 2

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	1.5E-02			
	Cancer fatalities	6.8E-02			
	Cancer incidence	2.9E-01	5.5E-08		
	Genetic effects	1.5E-02			
Noninvolved worker MEI	Dose (rem)	8.7E-02			
	Cancer fatalities	4.4E-05			
	Cancer incidence	1.5E-04	1.5E-11		
	Genetic effects	8.7E-06			
	Hazard index			2.8E-08	
Offsite population	Dose (person-rem)	1.9E+03			
	Cancer fatalities	8.7E-01			
	Cancer incidence	2.8	2.2E-07		
	Genetic effects	1.9E-01			
Offsite MEI	Dose (rem)	1.3E-01			
	Cancer fatalities	6.7E-05			
	Cancer incidence	2.3E-04	4.8E-12		
	Genetic effects	1.3E-05			
	Hazard index			1.1E-08	
WM workers	Dose (FTE-rem)	1.4E+03			
	Cancer fatalities	5.8E-01			
	Cancer incidence	2.0	2.4E-05		
	Genetic effects	8.8E-02			
	Exposure index			2.1E-06	
	Construction fatalities				2.2
	Construction injuries				8.6E+02
	Operation fatalities				1.4
	Operation injuries				1.1E+03

Table D.3.4–10. Programwide Risks Associated With Managing CH-TRUW Under Regionalized Alternative 3

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	3.6E+01			
	Cancer fatalities	1.8E–02			
	Cancer incidence	7.8E–02	5.6E–08		
	Genetic effects	3.6E–03			
Noninvolved worker MEI	Dose (rem)	2.8E–02			
	Cancer fatalities	1.4E–05			
	Cancer incidence	4.8E–05	1.5E–11		
	Genetic effects	2.8E–06			
	Hazard index			1.4E–10	
Offsite population	Dose (person-rem)	3.8E+02			
	Cancer fatalities	1.7E–01			
	Cancer incidence	6.5E–01	2.2E–07		
	Genetic effects	3.8E–02			
Offsite MEI	Dose (rem)	1.0E–02			
	Cancer fatalities	5.1E–06			
	Cancer incidence	1.7E–05	4.8E–12		
	Genetic effects	1.0E–06			
	Hazard index			7.9E–10	
WM workers	Dose (FTE-rem)	1.5E+03			
	Cancer fatalities	6.3E–01			
	Cancer incidence	2.2	3.5E–05		
	Genetic effects	9.4E–02			
	Exposure index			2.1E–06	
	Construction fatalities				1.8
	Construction injuries				7.0E+02
	Operation fatalities				1.1
	Operation injuries				7.9E+02

Table D.3.4-11. Programwide Risks Associated With Managing CH-TRUW Under the Centralized Alternative

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	4.2E-01			
	Cancer fatalities	2.1E-02			
	Cancer incidence	7.2E-02	6.3E-08		
	Genetic effects	4.2E-03			
Noninvolved worker MEI	Dose (rem)	1.6E-01			
	Cancer fatalities	8.2E-05			
	Cancer incidence	2.8E-04	1.3E-12		
	Genetic effects	1.6E-05			
	Hazard index			3.0E-10	
Offsite population	Dose (person-rem)	5.2E+02			
	Cancer fatalities	2.6E-01			
	Cancer incidence	8.9E-01	2.2E-07		
	Genetic effects	5.0E-02			
Offsite MEI	Dose (rem)	1.4E-01			
	Cancer fatalities	6.9E-05			
	Cancer incidence	2.3E-04	2.1E-13		
	Genetic effects	1.4E-05			
	Hazard index			4.9E-11	
WM workers	Dose (FTE-rem)	1.8E+03			
	Cancer fatalities	7.0E-01			
	Cancer incidence	2.5	5.1E-05		
	Genetic effects	1.0E-01			
	Exposure index			5.1E-04	
	Construction fatalities				1.1
	Construction injuries				4.3E-02
	Operation fatalities				5.0E-01
	Operation injuries				4.0E+02

Table D.3.4-12. Risks Associated With Managing CH-TRUW Under the No Action Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 457	4.6E-06	9.5E-11	9.2E-02	1.6E-05	3.2E-10	2.1E-01
INEL	153,061 55	2.6E-09	3.3E-13	1.1E-02	8.9E-09	1.1E-12	3.8E-06
LBL	5,856,829 0	4.8E-10	7.0E-15	3.4E-05	1.7E-09	2.5E-14	3.2E-12
LLNL	6,324,234 148	1.1E-06	1.8E-11	3.0E-02	3.8E-06	6.1E-11	2.5E-05
LANL	159,152 257	4.1E-06	4.4E-10	5.3E-02	1.4E-05	1.5E-09	1.2E-03
PGDP	500,502 0	0.00	0.00	0.00	0.00	0.00	0.00
Mound	3,032,983 0	0.00	0.00	0.00	0.00	0.00	0.00
NTS	14,266 0	0.00	0.00	0.00	0.00	0.00	0.00
RFETS	2,171,877 353	3.0E-06	4.1E-11	7.3E-02	1.0E-05	1.4E-10	2.9E-04
SNL-NM	610,714 0	0.00	0.00	0.00	0.00	0.00	0.00
SRS	620,618 320	2.2E-05	2.0E-10	6.3E-02	7.4E-05	6.9E-10	1.3E-01
ANL-E	7,939,785 106	5.5E-07	3.1E-12	2.2E-02	1.9E-06	1.0E-11	3.3E-06
Total		3.5E-05	4.4E-10	3.5E-01	1.2E-04	1.5E-09	3.4E-01

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.4-13. Risks Associated With Managing CH-TRUW Under the Decentralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 275	1.8E-06	9.9E-12	1.0E-01	6.1E-06	3.4E-11	3.0E-02
INEL	153,061 2,303	1.1E-06	1.4E-10	1.0	3.8E-06	4.8E-10	8.7E-01
LBL	5,856,829 1	6.3E-09	9.4E-14	8.4E-03	2.1E-08	3.2E-13	7.6E-09
LLNL	6,324,234 354	3.5E-06	5.7E-11	1.1E-01	1.2E-05	2.0E-10	2.0E-03
LANL	159,152 1,064	5.4E-05	5.7E-09	4.9E-01	1.8E-04	1.9E-08	5.0E-01
ORR	881,652 2	0.00	0.00	4.7E-04	0.00	0.00	7.9E-14
Mound	3,032,983 84	8.4E-07	4.8E-11	3.2E-02	2.9E-06	1.6E-10	4.8E-04
NTS	14,266 204	1.1E-10	3.0E-14	6.8E-02	3.9E-10	1.0E-13	7.3E-04
PGDP	500,502 15	3.5E-09	3.9E-13	1.3E-02	1.2E-08	1.3E-12	1.6E-06
RFETS	2,171,877 664	9.3E-06	1.3E-10	2.2E-01	3.2E-05	4.3E-10	2.7E-02
SNL-NM	610,714 2	2.7E-09	1.1E-13	8.7E-03	9.1E-09	3.6E-13	2.1E-08
SRS	620,618 550	7.2E-05	6.8E-10	1.5E-01	2.5E-04	2.3E-09	2.4E-01
Hanford	377,645 967	1.7E-05	3.5E-10	2.8E-01	5.7E-05	1.2E-09	4.4E-01
Total		1.6E-04	5.7E-09	2.5	5.5E-04	1.9E-08	2.1

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.4-14. Risks Associated With Managing CH-TRUW Under Regionalized Alternative 1, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 121	1.5E-06	8.5E-12	4.5E-02	5.2E-06	2.9E-11	3.0E-02
Hanford	377,645 1,330	3.0E-05	6.1E-10	3.5E-01	1.0E-04	2.1E-09	4.5E-01
INEL	153,061 3,100	1.4E-06	1.8E-10	1.2	4.9E-06	6.0E-10	8.7E-01
LBL	5,856,829 1	9.8E-09	1.5E-13	1.8E-04	3.4E-08	5.0E-13	7.5E-09
LLNL	6,324,234 186	3.6E-06	5.9E-11	5.7E-02	1.3E-05	2.1E-10	2.0E-03
LANL	159,152 1,502	6.5E-05	6.9E-09	6.4E-01	2.2E-04	2.3E-08	5.0E-01
PGDP	500,502 8	5.3E-09	5.9E-13	2.5E-03	1.8E-08	2.0E-12	1.7E-06
Mound	3,032,983 47	1.5E-06	8.6E-11	1.4E-02	5.1E-06	2.9E-10	4.7E-04
NTS	14,266 137	1.5E-10	3.9E-14	4.2E-02	5.1E-10	1.3E-13	7.0E-04
RFETS	2,171,877 989	1.5E-05	2.0E-10	3.4E-01	5.1E-05	6.9E-10	2.7E-02
SNL-NM	610,714 1	3.5E-09	1.4E-13	4.5E-04	1.2E-08	4.8E-13	2.1E-08
SRS	620,618 944	1.4E-04	1.3E-09	2.2E-01	4.6E-04	4.3E-09	2.7E-01
Total		2.6E-04	6.9E-09	3.0	8.6E-04	2.3E-08	2.2

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.4-15. Risks Associated With Managing CH-TRUW Under Regionalized Alternative 2, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 121	1.5E-06	8.5E-12	4.5E-02	5.2E-06	2.9E-11	3.0E-02
Hanford	377,645 2,150	1.7E-01	3.4E-06	4.3E-01	5.6E-01	1.2E-05	4.3E-01
INEL	153,061 5,364	7.3E-03	9.1E-07	1.8	2.5E-02	3.1E-06	8.3E-01
LBL	5,856,829 1	9.8E-09	1.5E-13	1.8E-04	3.4E-08	5.0E-13	7.5E-09
LLNL	6,324,234 186	3.6E-06	5.9E-11	5.7E-02	1.3E-05	2.1E-10	2.0E-03
LANL	159,152 2,772	6.4E-01	6.7E-05	9.6E-01	2.2	2.3E-04	4.8E-01
PGDP	500,502 8	5.3E-09	5.9E-13	2.5E-03	1.8E-08	2.0E-12	1.7E-06
Mound	3,032,983 47	1.5E-06	8.6E-11	1.4E-02	5.1E-06	2.9E-10	4.7E-04
NTS	14,266 137	1.5E-10	3.9E-14	4.2E-02	5.1E-10	1.3E-13	7.0E-04
RFETS	2,171,877 1,852	1.1E-01	1.5E-06	5.7E-01	3.7E-01	5.0E-06	2.5E-02
SNL-NM	610,714 1	3.5E-09	1.4E-13	4.5E-04	1.2E-08	4.8E-13	2.1E-08
SRS	620,618 1,408	2.3E-03	2.1E-08	2.6E-01	7.7E-03	7.2E-08	2.6E-01
Total		8.7E-01	6.7E-05	4.2	2.8	2.3E-04	2.0

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.4-16. Risks Associated With Managing CH-TRUW Under Regionalized Alternative 3, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 121	1.5E-06	8.5E-12	4.5E-02	5.2E-06	2.9E-11	3.0E-02
Hanford	377,645 2,150	1.7E-01	3.4E-06	4.3E-01	5.6E-01	1.2E-05	4.3E-01
INEL	153,061 6,277	4.1E-02	5.1E-06	2.1	1.4E-01	1.7E-05	8.7E-01
LBL	5,856,829 1	9.8E-09	1.5E-013	1.8E-04	3.4E-08	5.0E-13	7.5E-09
LLNL	6,324,234 186	3.6E-06	5.9E-11	5.7E-02	1.3E-05	2.1E-10	2.0E-03
LANL	159,152 713	7.1E-05	7.4E-09	3.8E-01	2.4E-04	2.5E-08	5.0E-01
PGDP	500,502 8	5.3E-09	5.9E-13	2.5E-03	1.8E-08	2.0E-12	1.7E-06
Mound	3,032,983 47	1.5E-06	8.6E-11	1.4E-02	5.1E-06	2.9E-10	4.7E-04
NTS	14,266 137	1.5E-10	3.9E-14	4.2E-02	5.1E-10	1.3E-13	7.0E-04
RFETS	2,171,877 420	1.2E-05	1.6E-10	1.6E-01	4.1E-05	5.6E-10	1.0E-01
SNL-NM	610,714 1	3.5E-09	1.4E-13	4.5E-04	1.2E-08	4.8E-13	2.1E-08
SRS	620,618 1,408	2.3E-03	2.1E-08	2.6E-01	7.7E-03	7.2E-08	2.6E-01
Total		1.7E-01	5.1E-06	3.5	6.5E-01	1.7E-05	2.2

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.4-17. Risks Associated With Managing CH-TRUW Under the Centralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
WIPP	99,889 4,132	2.6E-01	6.9E-05	4.6E-01	8.9E-01	2.3E-04	5.7E-02
ANL-E	7,939,785 121	1.5E-06	8.5E-12	4.5E-02	5.2E-06	2.9E-11	3.0E-02
Hanford	377,645 522	7.6E-06	1.6E-10	2.7E-01	2.6E-05	5.3E-10	5.6E-01
INEL	153,061 1,586	1.6E-06	2.0E-10	7.6E-01	5.3E-06	6.6E-10	8.5E-01
LBL	5,856,829 1	9.8E-09	1.5E-13	1.8E-04	3.4E-08	5.0E-13	7.5E-09
LLNL	6,324,234 186	3.6E-06	5.9E-11	5.7E-02	1.3E-05	2.1E-10	2.0E-03
LANL	159,152 713	7.1E-05	7.4E-09	3.8E-01	2.4E-04	2.5E-08	5.0E-01
PGDP	500,502 8	5.3E-09	5.9E-13	2.5E-03	1.8E-08	2.0E-12	1.7E-06
Mound	3,032,983 47	1.5E-06	8.6E-11	1.4E-02	5.1E-06	2.9E-10	4.7E-04
NTS	14,266 137	1.5E-10	3.9E-14	4.2E-02	5.1E-10	1.3E-13	7.0E-04
RFETS	2,171,877 420	1.2E-05	1.6E-10	1.6E-01	4.1E-05	5.6E-10	1.0E-01
SNL-NM	610,714 1	3.5E-09	1.4E-13	4.5E-04	1.2E-08	4.8E-13	2.1E-08
SRS	620,618 364	3.4E-05	3.2E-10	1.7E-01	1.2E-04	1.1E-09	3.6E-01
Total		2.6E-01	6.9E-05	2.3	8.9E-01	2.3E-04	2.5

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs ("worker equivalents") for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.4–18. CH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Site, by Alternative

Alternative	Installation													
	ANL-E	Hanford	INEL	LANL	LBL	LLNL	Mound	NTS	PGDP	RFETS	SNL-NM	SRS	ORR	WIPP
No Action	Pu-239[a] 4.21E-07[b]	Pu-238 3.05E-06	Am-241 1.34E-09	Am-241 2.14E-06	Pu-239 2.53E-10	Pu-239 5.68E-07	Pu-238 0.00	Pu-242 0.00	Pu-242 0.00	Am-241 1.59E-06	Pu-242 0.00	Pu-238 2.09E-05		
Decentralized	Pu-239 1.37E-06	Pu-238 1.12E-05	Am-241 5.84E-07	Am-241 2.80E-05	Pu-239 3.25E-09	Pu-239 1.79E-06	Pu-238 8.38E-07	Pu-239 2.29E-10	Pu-239 1.82E-09	Am-241 4.94E-06	Pu-239 1.38E-09	Pu-238 6.95E-05	Pu-242 0.00	
Regionalized 1	Pu-239 1.18E-06	Pu-238 1.93E-05	Am-241 7.39E-07	Am-241 3.42E-05	Pu-239 5.11E-09	Pu-239 1.88E-06	Pu-238 1.50E-06	Pu-239 3.01E-10	Pu-239 2.76E-09	Am-241 7.94E-06	Pu-239 1.81E-09	Pu-238 1.29E-04		
Regionalized 2	Pu-239 1.18E-06	Pu-238 1.06E-01	Am-241 3.80E-03	Am-241 3.33E-01	Pu-239 5.11E-09	Pu-239 1.88E-06	Pu-238 1.50E-06	Pu-239 3.01E-10	Pu-239 2.76E-09	Am-241 5.82E-02	Pu-239 1.81E-09	Pu-238 1.65E-03		
Regionalized 3	Pu-239 1.18E-06	Pu-238 1.06E-01	Am-241 2.13E-02	Am-241 3.68E-05	Pu-239 5.11E-09	Pu-239 1.88E-06	Pu-238 1.50E-06	Pu-239 3.01E-10	Pu-239 2.76E-09	Am-241 6.45E-06	Pu-239 1.81E-09	Pu-238 1.65E-03		
Centralized	Pu-239 1.18E-06	Pu-238 5.0E-06	Am-241 8.11E-07	Am-241 3.68E-05	Pu-239 5.11E-09	Pu-239 1.88E-06	Pu-238 1.50E-06	Pu-239 3.01E-10	Pu-239 2.76E-09	Am-241 6.45E-06	Pu-239 1.81E-09	Pu-238 3.28E-05		Pu-238 1.09E-01

[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

D.3.4.4 Results of the CH-TRUW Human Health Risk Analysis for Routine Operations

In general, No Action presents the lowest health risks for all public and worker populations and for all health risk endpoints because no waste treatment is performed other than packaging. For offsite and noninvolved worker receptors, the health risks associated with the other CH-TRUW alternatives generally increase as more extensive waste treatment is assumed; the alternatives with the highest estimated health risks are those involving treatment to meet RCRA LDRs. For workers, all alternatives that include waste treatment involve similar health risks. Overall, the health risks from exposure to chemicals in CH-TRUW are considerably lower than from exposure to radionuclides. In addition, the probability of adverse effects from noncarcinogenic, hazardous chemicals is very low. Estimated impacts to each receptor population are summarized below.

D.3.4.4.1 *Programwide Trends in Human Health Risks Associated With CH-TRUW Management Alternatives*

Offsite Population. Radiological and chemical exposure risks to the offsite population are lowest for No Action in which CH-TRUW is stored, without treatment, at the 16 generator sites in existing or approved facilities. The programwide risk of cancer fatality for this alternative is 3.5E–05 distributed over a total affected offsite population of approximately 28 million (see Tables D.3.4–3 and D.3.4–4). The exposure risks to offsite populations in Decentralized (in which wastes are treated to WIPP waste acceptance criteria and stored at 10 installations) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at 5 installations) are slightly higher than those for No Action and are distributed over a similar total population. Regionalized 2, 3, and Centralized, the three alternatives in which CH-TRUW receives the extensive treatment necessary to meet RCRA LDRs, show markedly higher risks to offsite populations than other alternatives, with 0.17 to 0.87 estimated cancer fatalities over a total population of approximately 28 million people.

The highest risks to the offsite population are associated with Regionalized 2 and 3 (in which wastes are treated to RCRA LDRs and stored at five and three sites, respectively). Estimated programwide cancer fatalities for all 12 sites in Regionalized 2 and 3 are 0.87 and 0.17, respectively, for a total offsite population of approximately 28 million. Tables D.3.4–15 and D.3.4–16 show that the predominant portion of the estimated cancer risks in Regionalized 2 and 3 are attributed to LANL and Hanford, respectively.

At LANL, 0.64 cancer fatalities are estimated to occur in the Regionalized 2 Alternative, while 4.1E-02 cancer fatalities are estimated to occur in Regionalized 3. These fatalities are estimated to occur in a population of 159,152 over a 10-year treatment period. In both the Regionalized 2 and 3 Alternatives, 0.17 cancer fatalities in a population of 377,645 at Hanford are estimated to occur over the 10-year treatment period. The higher estimated cancer risks at Hanford and LANL are linked to their relatively large inventory of plutonium-238 and americium-241, respectively (the larger the contaminant inventory with respect to other sites, the larger the amount of contaminant assumed to be released during treatment).

The risks of radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities. Estimated programwide risk of cancer incidence due to exposure to carcinogenic chemicals remains fairly consistent (in the E-07 order of magnitude) across alternatives except for No Action in which this estimated risk is slightly lower by approximately 1 order of magnitude.

Noninvolved Worker Population. The programwide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve much smaller affected populations (see Table D.3.4-4). Regionalized 2 poses the highest programwide risk to noninvolved worker populations (6.8E-02 total estimated cancer fatalities); however, the estimated cancer fatality risk for Regionalized 3 (1.8E-02) is only slightly lower than for Regionalized 2. The programwide risk of cancer incidence due to exposure to carcinogenic chemicals is in the E-08 order of magnitude in all except No Action, where it is slightly lower (by approximately 1 order of magnitude).

Maximally Exposed Noninvolved Worker and Offsite Individual. As shown in Table D.3.4-5, radiological exposure risks to the noninvolved worker and offsite MEIs are lowest for No Action, slightly higher for Decentralized and Regionalized 1, and highest by approximately 4 to 5 orders of magnitude for Regionalized 2, 3, and Centralized. This trend generally parallels that seen for noninvolved worker and offsite populations. The risk of cancer fatality for an MEI in Regionalized 2 and 3 are in the E-06 to E-05 range, and the highest risk of cancer fatality for an MEI is in the Centralized Alternative (8.8E-05 for the noninvolved worker MEI and 6.9E-05 for the offsite MEI). In the alternatives involving treatment to LDRs (Regionalized 2, 3, and Centralized), the risks of cancer incidence to the noninvolved worker and offsite MEIs from radionuclides exceed 1.0E-04.

Tables D.3.4-15 through D.3.4-17 show that the highest risks of cancer fatality to the offsite MEI are at LANL, Hanford, and RFETS in Regionalized 2; Hanford and INEL in Regionalized 3; and WIPP in the

Centralized Alternative. The elevated risks to the MEIs at these sites are due to two factors. First, in Regionalized 2 and 3, elevated cancer risks to the MEIs at LANL, Hanford, and RFETS result from increased exposure to emissions during treatment to LDRs. Second, in Regionalized 3 and Centralized, elevated cancer risks to the MEIs at INEL and WIPP result from a combination of increased emissions from treatment to LDRs and increased waste loads from consolidation.

All health risks due to chemical exposures are relatively low compared to radiation risks. Estimated risk of cancer incidence to each MEI due to chemical exposure is similar among alternatives and does not exceed the E-11 order of magnitude. In addition, the hazard indices for both MEIs are at least 9 orders of magnitude below 1.0 in all alternatives, indicating that adverse health effects from noncarcinogenic chemicals are unlikely.

Workers. As observed for public receptor populations, programwide radiological and chemical exposure risks to workers are lowest in No Action. Worker health risks for No Action are lower than for the other alternatives by approximately 1 order of magnitude (1.0E-01 estimated cancer fatalities over a population of 1,696 FTEs). No treatment is performed and fewer FTEs are required than in the other alternatives, resulting in less collective exposure. The estimated risk of cancer fatality (approximately 6.0E-01) and cancer incidence (approximately 2.0) due to radiation exposure are approximately equal in all but No Action, indicating that collective worker radiation exposure is relatively independent of the type of CH-TRUW treatment involved.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or the highest individual worker exposure to noncarcinogenic chemicals, follows the trend for the noninvolved worker and offsite MEIs (No Action is the lowest; Decentralized and Regionalized 1 are slightly higher; and Regionalized 2, 3, and Centralized are substantially higher). However, the exposure indices in all alternatives are at least 5 orders of magnitude below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents. The risk of worker cancer incidence from chemical exposure rises gradually across alternatives (lowest in No Action and slightly higher in the other alternatives). As seen with public receptor populations, chemical exposure contributes much less to worker health risk estimates than radiation exposure.

Estimated construction and operational fatalities are always higher than those associated with radiation exposure, regardless of alternative. No Action results in lower worker health risks from physical hazards because fewer person-hours are spent in construction and operation of facilities; therefore, injuries and fatalities are less likely. Regionalized 2 poses the highest risk of construction and operation fatalities of all the alternatives (3.6), reflecting the greatest number of person-hours devoted to these activities (see Table D.3.4–4).

Discussion. Radiation exposure risks from the routine management of CH-TRUW are substantially greater for all populations than chemical exposure risks; in addition, risks of worker fatalities due to physical hazards are always greater than those due to exposure.

For the offsite population, SRS consistently poses the highest estimated cancer fatalities for the No Action, Decentralized, and Regionalized 1 Alternatives. For the Regionalized 2, Regionalized 3, and Centralized Alternatives, LANL, Hanford, and WIPP pose the highest estimated cancer fatalities. The radionuclides contributing the most risk to the offsite population at Hanford and LANL in Regionalized 2 and 3 are americium and plutonium isotopes through inhalation and ingestion (see Table D.3.4–18). The controlling radionuclides are the same at WIPP in the Centralized Alternative, reflecting the consolidation of all installations' CH-TRUW at WIPP. Note that the cancer fatality risk to the offsite population is more than 4 orders of magnitude higher when Hanford treats its own waste than when its waste is treated at WIPP. This reflects the larger size and higher density of the population surrounding Hanford (compare the population distributions for Hanford and WIPP as shown in Tables D.3.4–19 and D.3.4–20).

For workers, the highest estimated total fatalities (cancer fatalities plus construction and operational fatalities) are associated with INEL in every alternative except No Action, where Hanford has the highest worker fatality risks, and Centralized, where WIPP has the highest number of total fatalities. As might be expected, for each alternative, the installation with the highest worker risk also has the highest number of FTEs involved in CH-TRUW management. The radionuclides contributing the most risk for workers at these sites are uranium-238 and uranium-235 at INEL via inhalation; and cesium-137 at Hanford and WIPP via external exposure.

Table D.3.4–19. Population Distribution Around Hanford on the Basis of the 1990 U.S. Census

Direction From Site	Distance From Site										
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km	Total
S	0.00	0.00	0.00	0.00	0.00	0.00	3,063.00	1,277.00	211.00	3,006.00	7,557.00
SSW	0.00	0.00	0.00	0.00	0.00	0.00	303.00	8,841.00	138.00	202.00	9,484.00
SW	0.00	0.00	0.00	0.00	0.00	0.00	24.00	25,654.00	4,298.00	90.00	30,066.00
WSW	0.00	0.00	0.00	0.00	0.00	0.00	35.00	2,012.00	18,451.00	5,004.00	25,502.00
W	0.00	0.00	0.00	0.00	0.00	0.00	23.00	38.00	2,833.00	101,475.00	104,369.00
WNW	0.00	0.00	0.00	0.00	0.00	0.00	764.00	159.00	0.00	3,669.00	4,592.00
NW	0.00	0.00	0.00	0.00	0.00	0.00	299.00	1,405.00	114.00	460.00	2,278.00
NNW	0.00	0.00	0.00	0.00	0.00	0.00	284.00	516.00	1,030.00	5,804.00	7,634.00
N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,121.00	369.00	2,003.00	4,493.00
NNE	0.00	0.00	0.00	0.00	0.00	0.00	75.00	721.00	3,623.00	19,894.00	24,313.00
NE	0.00	0.00	0.00	0.00	0.00	0.00	55.00	8,779.00	2,491.00	369.00	11,694.00
ENE	0.00	0.00	0.00	0.00	0.00	0.00	571.00	703.00	2,371.00	187.00	3,832.00
E	0.00	0.00	0.00	0.00	0.00	0.00	1,377.00	844.00	125.00	294.00	2,640.00
ESE	0.00	0.00	0.00	0.00	0.00	0.00	678.00	995.00	207.00	271.00	2,151.00
SE	0.00	0.00	0.00	0.00	0.00	0.00	183.00	42,497.00	55,888.00	297.00	98,865.00
SSE	0.00	0.00	0.00	0.00	0.00	0.00	2,342.00	28,710.00	556.00	6,567.00	38,175.00
Total	0.00	0.00	0.00	0.00	0.00	0.00	10,076.00	125,272.00	92,705.000	149,592.00	377,645.00

Table D.3.4-20. Population Distribution Around the Waste Isolation Pilot Plant (WIPP) on the Basis of the 1990 U.S. Census

Direction From Site	Distance From Site										
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km	Total
S	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.00	46.00	20.00	71.00
SSW	9.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	43.00	8.00	62.00
SW	0.00	0.00	0.00	0.00	0.00	0.00	37.00	57.00	0.00	5.00	99.00
WSW	0.00	0.00	0.00	0.00	0.00	0.00	1,622.00	191.00	57.00	62.00	1,932.00
W	0.00	0.00	0.00	0.00	0.00	0.00	138.00	25,291.00	197.00	3.00	25,629.00
WNW	0.00	0.00	0.00	0.00	0.00	0.00	38.00	5,765.00	242.00	63.00	6,108.00
NW	0.00	0.00	0.00	0.00	0.00	0.00	6.00	7.00	14.00	12,401.00	12,428.00
NNW	0.00	0.00	0.00	0.00	0.00	9.00	4.00	66.00	104.00	56.00	239.00
N	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	63.00	12.00	78.00
NNE	0.00	0.00	0.00	0.00	0.00	0.00	4.00	3.00	122.00	7,353.00	7,482.00
NE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	37.00	9,115.00	9,163.00
ENE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	282.00	30,877.00	31,169.00
E	0.00	0.00	0.00	0.00	0.00	0.00	6.00	5.00	2,982.00	19.00	3,012.00
ESE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	2,173.00	97.00	2,286.00
SE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	20.00	35.00
SSE	0.00	0.00	0.00	0.00	0.00	1.00	3.00	14.00	5.00	73.00	96.00
TOTAL	9.00	0.00	0.00	0.00	0.00	10.00	1,864.00	31,440.00	6,382.00	60,184.00	99,889.00

D.3.4.4.2 *Comparison of the Decentralized Alternative and Regionalized Alternative 1: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation*

A comparison of the Decentralized Alternative, in which CH-TRUW is stored and treated to WIPP waste acceptance criteria at 10 installations, and Regionalized 1, in which CH-TRUW is stored and treated to reduce gas generation at five installations, shows few differences in the health risks associated with these two treatment and consolidation options. The major difference between treating to WIPP waste acceptance criteria and treating to reduce gas generation is the addition of a waste shredding step in Regionalized 1, therefore, treatment risks should not be substantially different. The number of installations at which waste is consolidated also does not greatly affect the overall health risks.

D.3.4.4.3 *Comparison of Regionalized Alternatives 1 and 2: Treatment to Reduce Gas Generation Versus Treatment to Meet Land Disposal Restrictions*

A more controlled comparison of treatment risks can be made between Regionalized 1 and 2 since consolidation schemes are identical (wastes are treated and stored at the same five sites in both alternatives) but treatments differ (treatment to reduce gas generation in Regionalized 1 versus treatment to LDRs in Regionalized 2). As previously noted, the programwide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment to LDRs in Regionalized 2 are approximately 3 orders of magnitude greater for the offsite and noninvolved worker populations and MEIs than the risks from treatment for minimization of gas generation in Regionalized 1. While these radionuclide-related health effects differ between the two alternatives, the contribution of chemical carcinogens to cancer incidence is almost the same in each alternative for each population.

The programwide risks to workers from radionuclide exposure are nearly the same in Regionalized 1 and 2. In addition, the risk of chemical-related cancer incidence in workers is nearly identical between alternatives. This reflects the fact that collective worker exposure is similar between the alternatives, regardless of the different treatment options.

The offsite and noninvolved worker MEI hazard indices for Regionalized 2 are approximately 1 order of magnitude higher than in Regionalized 1, and the Regionalized 2 worker exposure index is about 1 order of magnitude higher than in Regionalized 1. This trend reflects the potential for higher individual exposure

to noncarcinogenic hazardous chemicals when CH-TRUW is treated to LDRs. However, in all alternatives, exposures to noncarcinogenic, hazardous chemicals yield hazard indices well below 1.0.

D.3.4.4.4 *Comparison of the Regionalized 2, 3, and Centralized Alternatives: Differences in Consolidation Configuration*

Examination of the Regionalized 2 and Centralized Alternatives provides a comparison of consolidation and interim storage configurations; in these three alternatives, wastes are treated to LDRs but are consolidated and stored at five, three, and one site(s), respectively. As discussed above, the programwide radiation exposure risks to all populations are very similar across all three alternatives with certain exceptions: In the Centralized Alternative, the risk of cancer fatality, cancer incidence, and genetic effects to offsite populations is less than 1 order of magnitude lower than the risks in Regionalized 2 and 3 because of the smaller population size and lower population density at WIPP compared to sites such as LANL, INEL, and Hanford. Also, the population at only one site, rather than several, is being exposed. However, the risks to the offsite and noninvolved worker MEIs are slightly higher in the Centralized Alternative than in Regionalized 2 and 3. These higher risks could be due to a combination of factors including the proximity of neighboring ranches to WIPP and the influence of weather conditions such as wind speed and direction. As previously noted, the estimated cancer incidence risks to the offsite and noninvolved worker MEIs are 2.3E–04 and 2.8E–04, respectively.

Risk of cancer incidence due to chemical exposure is within the same order of magnitude for all public receptor populations in all three alternatives. The hazard index for the offsite MEI in Regionalized 3 is slightly lower than the Regionalized 2 or Centralized estimates.

Worker radiation and chemical exposure risks are similar among the Regionalized 2, 3, and Centralized Alternatives.

D.3.4.4.5 *Summary of the Human Health Risk Analysis for Routine Management of CH-TRUW*

In summary, the No Action Alternative presents the fewest health risk to all populations. Health risks generally increase for the public receptors as more extensive treatment of CH-TRUW is assumed. Overall health risks to workers do not differ appreciably with different treatment options. The primary risk drivers for the public receptor populations are radiation exposure (as opposed to chemical exposure) and treatment option. For workers, the primary risk drivers are the size of the waste load and the person-hours necessary to process it.

D.3.4.5 Summary of RH-TRUW Alternatives

The PEIS waste management alternatives (No Action, Decentralization, Regionalization, and Centralization) and the rationale for developing the various RH-TRUW analysis alternatives are discussed rigorously in the main body of the PEIS. Four alternatives are analyzed for the RH-TRUW human health risk analysis:

- The No Action Alternative demonstrates the baseline risks of RH-TRUW retrieval, packaging, certification, and indefinite interim storage at ANL-E, Hanford, INEL, LANL, ORR and SRS. Treatment is not considered and it is assumed that TRUW will not be disposed of at WIPP.
- In the Decentralized Alternative, risks are estimated for building additional treatment facilities as required, treating wastes to WIPP waste acceptance criteria, and storing them at the six sites pending disposal at WIPP.
- In the Regionalized Alternative 1, RH-TRUW is consolidated, treated to minimize gas generation, and stored at Hanford and ORR.
- In the Regionalized 2, 3, and Centralized Alternatives, RH-TRUW is consolidated, treated to meet RCRA LDRs, and stored at Hanford and ORR. (This scenario makes it possible to contrast the risks of different levels of treatment of RH-TRUW by comparison with Regionalized Alternative 1.)

Table D.3.4–21 presents the overall treatment and storage schemes for these RH-TRUW alternatives. Table D.3.4–22 shows which sites will ship their wastes to regionalized or centralized consolidation sites for treatment and storage. Note that for the purposes of this risk analysis, the waste load from a smaller generator, ANL-W, was added to the inventory of INEL, a larger generator (ANL, 1996b), as the two sites are in close proximity to one another.

The discussion of the risk analysis results will address the overall health risk trends across the alternatives discussed above, comparisons among alternatives, higher-risk sites and alternatives, and major factors driving the estimated risks.

Table D.3.4–21. PEIS Alternatives for RH-TRUW

Alternative	ANL-E	Hanford	INEL	LANL	ORR	SRS
No Action Alternative No treatment; store at 6 sites	T	T	T	T	T	T
	S	S	S	S	S	S
Decentralized Alternative Treat to WIPP-WAC and store at 6 sites	T	T	T	T	T	T
	S	S	S	S	S	S
Regionalized Alternative 1 Treat to reduce gas and store at 2 sites		T			T	
		S			S	
Regionalized Alternatives 2, 3, and Centralized Alternative Treat to RCRA LDRs and store at 2 sites		T			T	
		S			S	

Notes: T = treatment installation; S = storage installation.

Table D.3.4–22. PEIS Consolidation and Treatment Strategies for RH-TRUW

Alternative	Origin	Treatment and Storage Destination
No Action Alternative No treatment; store at 6 sites	All sites	Generators store own waste
Decentralized Alternative Treat to WIPP-WAC and store at 6 sites	All sites	Generators treat and store own waste
Regionalized Alternative 1 Treat to minimize gas generation and store at 2 sites	Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E, SRS	Hanford ORR
Regionalized Alternatives 2, 3, and Centralized Alternative Treat to RCRA LDRs and store at 2 sites	Hanford, INEL/ANL-W[a], LANL, ORR, ANL-E, SRS	Hanford ORR

[a] For the purpose of the human health risk analysis, the ANL-W waste load is added to the INEL waste load.

D.3.4.6 Results Tables for the RH-TRUW Human Health Risk Analysis

This section contains the results tables for the RH-TRUW human health risk analysis. A discussion of the results is presented in Section D.3.4.7. The fatality and cancer incidence numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.4–23 presents an overview, by alternative, of the *total*, programwide risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers. These tables provide the estimated *total number* of people in the three populations who will develop or die of cancers caused by exposure to RH-TRUW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed in construction and operational activities.
- Table D.3.4–24 shows the sizes of the total affected populations for each alternative.
- Table D.3.4–25 summarizes the risks to the noninvolved worker MEI and offsite MEI for each RH-TRUW alternative. The numbers in this table are the estimated *probabilities* that the noninvolved worker and offsite MEIs will die of or develop cancer from radionuclide or chemical exposure, or indicators of the likelihood of suffering adverse health effects from exposure to noncarcinogenic, hazardous constituents.
- Tables D.3.4–26 through D.3.4–29 show the programwide risks for all receptors and health effect endpoints, by alternative.
- Tables D.3.4–30 through D.3.4–33 present offsite and worker population risks for each installation, by alternative.
- Table D.3.4–34 lists the radionuclides that contribute most of the risk to the offsite population, by installation and alternative.

Table D.3.4-23. Summary of Programwide Risks Associated With Routine Management of RH-TRUW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF	CI	CF	CI	CF	CI	C&OF
No Action	2.8E-06	9.6E-06	1.3E-07	4.3E-07	6.2E-02	2.2E-01	7.1E-02
Decentralized	7.4E-06	2.5E-05	3.3E-07	1.1E-06	4.3E-03	1.5E-02	3.0E-01
Regionalized 1	1.3E-05	4.3E-05	5.7E-07	1.9E-06	6.2E-03	2.2E-02	3.3E-01
Regionalized 2, 3, and Centralized	4.6E-02	1.6E-01	1.6E-03	5.4E-03	9.6E-02	3.4E-01	4.6E-01

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides and carcinogenic chemicals; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.4-24. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of RH-TRUW, by Alternative

Alternative	Offsite	Noninvolved Worker	WM Worker
No Action	10,131,913	38,057	59
Decentralized	10,131,913	38,057	1,109
Regionalized 1	10,131,913	38,057	1,469
Regionalized 2, 3, and Centralized	10,131,913	38,057	2,326

Table D.3.4-25. Summary of Programwide Risks Associated With Routine Management of RH-TRUW: Risks to the Maximally Exposed Offsite Individual and Maximally Exposed Noninvolved Worker, by Alternative

Alternative	Offsite MEI				Noninvolved Worker MEI			
	CF	Rad CI	Chem CI	HI	CF	Rad CI	Chem CI	HI
No Action	5.5E-11	1.9E-10	4.0E-13	3.5E-12	2.1E-10	7.2E-10	2.5E-12	2.8E-11
Decentralized	1.3E-10	4.5E-10	8.1E-12	1.3E-10	5.1E-10	1.7E-09	5.0E-11	8.0E-10
Regionalized 1	2.4E-10	8.3E-10	8.1E-12	1.3E-10	9.2E-10	3.1E-09	5.1E-11	7.7E-10
Regionalized 2, 3, and Centralized	1.3E-06	4.4E-06	5.7E-12	1.8E-09	1.1E-06	3.6E-06	3.5E-11	9.3E-09

Notes: CF = cancer fatality associated with exposure to radionuclides; Rad CI = cancer incidence associated with exposure to radionuclides; Chem CI = cancer incidence associated with exposure to carcinogenic chemicals; HI = hazard index associated with exposure to noncarcinogenic, toxic chemicals.

Table D.3.4-26. Programwide Risks Associated With Treatment of RH-TRUW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	2.5E-04			
	Cancer fatalities	1.3E-07			
	Cancer incidence	4.3E-07	2.6E-09		
	Genetic effects	2.5E-08			
Noninvolved worker MEI	Dose (rem)	4.3E-07			
	Cancer fatalities	2.1E-10			
	Cancer incidence	7.2E-10	2.5E-12		
	Genetic effects	4.3E-11			
	Hazard index			2.8E-11	
Offsite population	Dose (person-rem)	5.7E-03			
	Cancer fatalities	2.8E-06			
	Cancer incidence	9.6E-06	8.1E-09		
	Genetic effects	5.7E-07			
Offsite MEI	Dose (rem)	1.1E-07			
	Cancer fatalities	5.5E-11			
	Cancer incidence	1.9E-10	4.0E-13		
	Genetic effects	1.1E-11			
	Hazard index			3.5E-12	
WM workers	Dose (FTE-rem)	1.5E+02			
	Cancer fatalities	6.2E-02			
	Cancer incidence	2.2E-01	9.0E-08		
	Genetic effects	9.3E-03			
	Exposure index			3.7E-06	
	Construction fatalities				3.5E-02
	Construction injuries				1.1E+01
	Operation fatalities				3.6E-02
	Operation injuries				1.6E-01

Table D.3.4-27. Programwide Risks Associated With Treatment of RH-TRUW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	6.4E-04			
	Cancer fatalities	3.3E-07			
	Cancer incidence	1.1E-06	5.2E-08		
	Genetic effects	6.4E-08			
Noninvolved worker MEI	Dose (rem)	1.0E-06			
	Cancer fatalities	5.0E-10			
	Cancer incidence	1.7E-09	5.0E-11		
	Genetic effects	1.0E-10			
	Hazard index			8.0E-10	
Offsite population	Dose (person-rem)	1.5E-02			
	Cancer fatalities	7.4E-06			
	Cancer incidence	2.5E-05	1.6E-07		
	Genetic effects	1.5E-06			
Offsite MEI	Dose (rem)	2.7E-07			
	Cancer fatalities	1.3E-10			
	Cancer incidence	4.5E-10	8.1E-12		
	Genetic effects	2.7E-11			
	Hazard index			1.3E-10	
WM workers	Dose (FTE-rem)	1.1E+01			
	Cancer fatalities	4.3E-03			
	Cancer incidence	1.5E-02	3.0E-06		
	Genetic effects	6.3E-04			
	Exposure index			3.1E-05	
	Construction fatalities				2.0E-01
	Construction injuries				7.8E+01
	Operation fatalities				1.0E-01
	Operation injuries				6.7E+01

Table D.3.4-28. Programwide Risks Associated With Treatment of RH-TRUW Under Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	1.1E-03			
	Cancer fatalities	5.7E-07			
	Cancer incidence	1.9E-06	5.2E-08		
	Genetic effects	1.1E-07			
Noninvolved worker MEI	Dose (rem)	1.9E-06			
	Cancer fatalities	9.3E-10			
	Cancer incidence	3.1E-09	5.0E-11		
	Genetic effects	1.9E-10			
	Hazard index			8.0E-10	
Offsite population	Dose (person-rem)	2.6E-02			
	Cancer fatalities	1.3E-05			
	Cancer incidence	4.3E-05	1.6E-07		
	Genetic effects	2.6E-06			
Offsite MEI	Dose (rem)	4.9E-07			
	Cancer fatalities	2.4E-10			
	Cancer incidence	8.3E-10	8.1E-12		
	Genetic effects	4.9E-11			
	Hazard index			1.3E-10	
WM workers	Dose (FTE-rem)	1.6E+01			
	Cancer fatalities	6.2E-03			
	Cancer incidence	2.2E-02	3.4E-06		
	Genetic effects	9.3E-04			
	Exposure index			3.1E-05	
	Construction fatalities				2.3E-01
	Construction injuries				7.8E+01
	Operation fatalities				1.0E-01
	Operation injuries				5.8E+01

Table D.3.4-29. Programwide Risks Associated With Treatment of RH-TRUW Under Regionalized Alternatives 2 and 3 and the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	3.2			
	Cancer fatalities	1.6E-03			
	Cancer incidence	5.4E-03	3.7E-08		
	Genetic effects	3.2E-04			
Noninvolved worker MEI	Dose (rem)	2.8E-03			
	Cancer fatalities	1.4E-06			
	Cancer incidence	4.8E-06	3.5E-11		
	Genetic effects	2.8E-07			
	Hazard index			1.2E-08	
Offsite population	Dose (person-rem)	8.9E+01			
	Cancer fatalities	4.6E-02			
	Cancer incidence	1.6E-01	1.1E-07		
	Genetic effects	8.9E-03			
Offsite MEI	Dose (rem)	2.8E-03			
	Cancer fatalities	1.4E-06			
	Cancer incidence	4.8E-06	5.7E-12		
	Genetic effects	2.8E-07			
	Hazard index			1.9E-09	
WM workers	Dose (FTE-rem)	2.4E+02			
	Cancer fatalities	9.6E-02			
	Cancer incidence	3.4E-01	5.2E-06		
	Genetic effects	1.4E-02			
	Exposure index			2.4E-05	
	Construction fatalities				3.1E-01
	Construction injuries				1.2E+02
	Operation fatalities				1.5E-01
	Operation injuries				9.4E+01

Table D.3.4-30. Risks Associated With Treatment of RH-TRUW Under the No Action Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 30	7.4E-08	4.1E-13	6.1E-03	2.5E-07	1.4E-12	1.0E-07
Hanford	377,645 442	2.7E-06	5.6E-11	1.0E-01	9.1E-06	1.9E-10	2.2E-01
INEL	153,061 77	4.1E-09	5.1E-13	1.6E-02	1.4E-08	1.7E-12	1.0E-05
LANL	159,152 5	6.7E-10	7.0E-14	1.1E-03	2.3E-09	2.4E-13	3.5E-09
ORR	881,652 41	6.6E-08	2.1E-12	8.4E-03	2.3E-07	7.4E-12	1.3E-06
SRS	620,618 4	5.1E-09	4.8E-14	3.2E-04	1.7E-08	1.6E-13	5.5E-06
Total		2.8E-06	5.6E-11	1.3E-01	9.6E-06	1.9E-10	2.2E-01

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.4-31. Risks Associated With Treatment of RH-TRUW Under the Decentralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 62	1.9E-07	1.1E-12	2.6E-02	6.5E-07	3.6E-12	5.8E-04
Hanford	377,645 552	6.4E-06	1.3E-10	1.0E-01	2.2E-05	4.5E-10	6.8E-04
INEL	153,061 168	1.2E-08	1.6E-12	5.9E-02	4.2E-08	5.3E-12	3.7E-03
LANL	159,152 51	2.0E-08	2.1E-12	2.3E-02	6.7E-08	7.1E-12	4.8E-04
ORR	881,652 270	8.0E-07	2.5E-11	9.3E-02	2.9E-06	9.2E-11	9.5E-03
SRS	620,618 6	1.3E-08	1.2E-13	5.8E-03	4.4E-08	4.1E-13	2.8E-07
Total		7.4E-06	1.3E-10	3.1E-01	2.6E-05	4.5E-10	1.5E-02

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.4–32. Risks Associated With Treatment of RH-TRUW Under Regionalized Alternative 1, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 29	2.0E-07	1.1E-12	8.9E-03	6.9E-07	3.8E-12	5.2E-04
Hanford	377,645 982	1.2E-05	2.4E-10	1.7E-01	4.0E-05	8.3E-10	7.5E-03
INEL	153,061 105	1.6E-08	2.0E-12	3.3E-02	5.4E-08	6.7E-12	3.5E-03
LANL	159,152 35	2.5E-08	2.6E-12	1.1E-02	8.5E-08	9.0E-12	4.6E-04
ORR	881,652 314	8.3E-07	2.6E-11	1.1E-01	3.0E-06	9.5E-11	9.7E-03
SRS	620,618 4	5.7E-09	5.4E-14	6.9E-04	1.9E-08	1.8E-13	9.9E-06
Total		1.3E-05	2.4E-10	3.3E-01	4.4E-05	8.3E-10	2.2E-02

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.4–33. Risks Associated With Treatment of RH-TRUW Under Regionalized Alternatives 2 and 3 and the Centralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
LANL	159,152 35	2.5E-08	2.6E-12	1.1E-02	8.5E-08	9.0E-12	4.6E-04
ORR	881,652 682	4.6E-02	1.4E-06	3.0E-01	1.6E-01	4.8E-06	3.2E-01
ANL-E	7,939,785 29	2.0E-07	1.1E-12	8.9E-03	6.9E-07	3.8E-12	5.2E-04
Hanford	377,645 1,471	6.4E-04	1.3E-08	2.1E-01	2.2E-03	4.5E-08	1.4E-02
INEL	153,061 105	1.6E-08	2.0E-12	3.3E-02	5.4E-08	6.7E-12	3.5E-03
SRS	620,618 4	5.7E-09	5.4E-14	6.9E-04	1.9E-08	1.8E-13	9.9E-06
Total		4.7E-02	1.4E-06	5.6E-01	1.6E-01	4.8E-06	3.4E-01

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with radiation exposure and physical hazards.
[c] Indicates cancer incidence associated with radiation exposure.

Table D.3.4–34. RH-TRUW Radionuclides Contributing the Highest Risk of Cancer Fatality to the Offsite Population at Each Site, by Alternative

Alternative	Site					
	ANL-E	**Hanford**	**INEL**	**LANL**	**ORR**	**SRS**
No Action	Pu-239[a] 3.13E–08[b]	Pu-239 9.0E–07	Pu-241 2.13E–09	Pu-239 3.53E–10	Cm-244 3.22E–08	Pu-238 3.0E–09
Decentralized	Pu-239 8.02E–08	Pu-239 2.1E–06	Pu-241 6.64E–09	Pu-239 1.04E–08	Cm-244 3.75E–07	Pu-238 8.0E–09
Regionalized 1	Pu-239 8.53E–08	Pu-239 3.9E–06	Pu-241 8.46E–09	Pu-239 1.31E–08	Cm-244 3.75E–07	Pu-238 3.0E–09
Regionalized 2, 3, and Centralized	Pu-239 8.53E–08	Pu-239 4.3E–04	Pu-241 8.46E–09	Pu-239 1.31E–08	Cm-244 2.11E–02	Pu-238 3.0E–09

[a] Radionuclide contributing most risk of cancer fatality.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

D.3.4.7 Results of the RH-TRUW Human Health Risk Analysis

D.3.4.7.1 *Programwide Trends in Human Health Risks Associated With RH-TRUW Management Alternatives*

In general, the overall risks associated with managing RH-TRUW are somewhat lower than the risks from managing CH-TRUW. No Action presents the lowest health risks for all public and noninvolved worker populations and for all health risk endpoints because there is no waste treatment other than packaging. For the offsite, noninvolved worker, and worker populations, the health risks associated with the remaining RH-TRUW alternatives generally increase as more extensive waste treatment is employed; the highest estimated health risks are for the RH-TRUW scenario associated with the Regionalized 2, 3, and Centralized Alternatives, which involves incinerating RH-TRUW to destroy organic chemicals to meet RCRA LDRs. For workers, health risks are similar among the alternatives that include waste treatment. Overall, the health risks from exposure to chemicals in RH-TRUW are lower than from exposure to radionuclides, and the probability of adverse effects from noncarcinogenic, hazardous chemicals is very low. Estimated impacts to each receptor population are summarized below.

Offsite Population. Radiological and chemical exposure risks to the offsite population are lowest for No Action in which RH-TRUW is stored, without treatment, at the six generator sites in existing or approved facilities. The programwide risk of cancer fatality for this alternative is 2.8E–06 distributed over a total affected offsite population of approximately 10 million (see Tables D.3.4–23 and D.3.4–24).

The exposure risks to offsite populations in Decentralized (in which wastes are treated to WIPP waste acceptance criteria and stored at six sites) and Regionalized 1 (in which wastes are treated to reduce gas generation and stored at two sites) are slightly higher than those for No Action and are distributed over a similar total population. Treatment of RH-TRUW to LDRs and storage at two sites (Regionalized 2, 3, and Centralized Alternatives) results in markedly higher risks to offsite populations than in the other alternatives, with 4.6E–02 estimated cancer fatalities over a total population of approximately 10 million people.

Table D.3.4–33 shows that the predominant portion of the estimated cancer risks when RH-TRUW is treated to meet LDRs and stored at Hanford and ORR (Regionalized 2, 3, and Centralized Alternatives) is

attributed to ORR, where 4.6E–02 cancer fatalities in a population of 881,652 are estimated to occur over the 10-year treatment period. The higher estimated cancer risks at this site are linked to its relatively large inventory of curium-244 (the larger the contaminant inventory with respect to other sites, the larger the amount of contaminant assumed to be released during treatment).

Estimated programwide risks of cancer incidence from exposure to carcinogenic chemicals remain fairly consistent across alternatives, in the E–07 order of magnitude in all alternatives except No Action, in which cancer incidence risk is 8.1E–09 for the offsite population.

Noninvolved Worker Population. The programwide health risks to noninvolved worker populations parallel the trends observed for offsite populations but are slightly lower and involve a smaller affected population of 38,057 (see Table D.3.4–24). Treatment of RH-TRUW to LDRs and storage at two sites (Regionalized 2, 3, and Centralized Alternatives) poses the highest programwide risk to noninvolved worker populations (1.6E–03 total estimated cancer fatalities). The risk of cancer incidence due to exposure to carcinogenic chemicals is in the E–08 order of magnitude in all except No Action, where it is lower by approximately 1 order of magnitude (see Tables D.3.4–26 through D.3.4–29).

Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual. As shown in Table D.3.4–25, radiological risks to the noninvolved worker and offsite MEIs are lowest in No Action, slightly higher in Decentralized and Regionalized 1, and highest by approximately 4 orders of magnitude in the other alternatives (where RH-TRUW is treated to LDRs and stored at ORR and Hanford). Risks from chemical exposure follow a similar pattern. These trends generally parallel that seen for the total noninvolved worker and offsite populations.

Tables D.3.4–30 through D.3.4–33 show that the highest risks of cancer fatality to the offsite MEI are at Hanford and ORR in the Regionalized 2, 3, and Centralized Alternatives. These elevated risks are due to increased exposure from emissions during treatment to LDRs.

On the program level, estimated risk of cancer incidence due to chemical exposure is similar among alternatives and does not exceed the E–11 order of magnitude. While both MEI hazard indices are 2–3 orders of magnitude higher in Regionalized 2, 3, and Centralized than in No Action, the hazard indices in all alternatives are well below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents.

Workers. All exposures to FTEs are below regulatory limits. As was the case for CH-TRUW, RH-TRUW worker exposure and physical hazard risks generally increase as treatment increases in extent. Estimated construction and operational fatalities are always higher than those associated with radiation exposure, regardless of alternative. No Action results in lower worker health risks from physical hazards because fewer person-hours are spent in construction and operation of facilities, therefore injuries and fatalities are less likely. The risks from physical hazards are highest for the alternatives involving treatment (all except No Action) and are similar among these alternatives. Programwide radiological risks to workers are among the lowest in No Action (6.2E–02 estimated cancer fatalities over a population of 59 FTEs), slightly lower in Decentralized and Regionalized 1 (4.3E–03 and 6.2E–03, respectively), and increase somewhat in the other alternatives.

Worker health risks associated with chemical exposure vary slightly among alternatives. The exposure index, or highest individual worker exposure to noncarcinogenic chemicals, is approximately 1 order of magnitude lower in No Action than for the alternatives that involve treatment. However, in all alternatives the exposure indices are well below 1.0, indicating a low probability of adverse health effects from noncarcinogenic, hazardous constituents. The risk of worker cancer incidence from chemical exposure rises gradually across alternatives (lowest in No Action and slightly higher in the Decentralized, Regionalized, and Centralized Alternatives). Chemical exposure contributes much less to worker health risk estimates than radiation exposure.

Discussion. As stated above, radiation exposure risks are greater than chemical exposure risks for RH-TRUW for all populations by several orders of magnitude. The risks of worker fatalities due to physical hazards are always greater than those due to exposure.

For the offsite population, Hanford poses the highest estimated cancer fatalities in all alternatives except Regionalized 2, 3, and Centralized, where the highest risk is at ORR. The radionuclides contributing the most risk to the offsite population are plutonium-239 at Hanford in No Action, Decentralized, and Regionalized 1–3, and Centralized; and curium-244 at ORR in Regionalized 2, 3, and Centralized (see Table D.3.4–34).

For workers, the highest estimated total fatalities (cancer fatalities plus construction and operational fatalities) in all alternatives are associated with Hanford, where the most FTEs are involved in RH-TRUW management. Total fatality risks (as well as numbers of FTEs) are second highest at INEL in No Action, and at ORR in all other alternatives. In No Action, the radionuclides contributing the most worker risk are plutonium-241 at INEL, through inhalation; and plutonium-238 at Hanford, through inhalation. The controlling radionuclides for worker risks in Decentralized are uranium-236 at Hanford, through inhalation; and europium-152 and its radioactive decay products at ORR, through external exposure. In Regionalized 1 at Hanford, and in Regionalized 2, 3, and Centralized at ORR and Hanford, the controlling radionuclide is uranium-233, through inhalation.

D.3.4.7.2 *Comparison of the Decentralized and Regionalized 1 Alternatives: Treatment to WIPP Waste Acceptance Criteria Versus Treatment to Reduce Gas Generation*

A comparison of Decentralized (in which RH-TRUW is treated to WIPP waste acceptance criteria and stored at six installations) and Regionalized 1 (in which RH-TRUW is treated to reduce gas generation and stored at two installations) shows few differences in the health risks associated with these two treatment and consolidation options. The major difference between treating to WIPP waste acceptance criteria and treating to reduce gas generation is the addition of a waste shredding step in Regionalized 1, therefore, treatment risks should not be substantially different. The number of installations at which waste is consolidated also does not greatly affect the overall health risks.

D.3.4.7.3 *Comparison of Regionalized Alternative 1 With Regionalized Alternatives 2 and 3 and the Centralized Alternative: Treatment to Reduce Gas Generation Versus Treatment to Meet Land Disposal Restrictions*

A more controlled comparison of treatment risks can be made between the Regionalized 1 and the Regionalized 2 and 3, and Centralized Alternatives since consolidation schemes are identical (wastes are treated and stored at the same two installations in all of these alternatives) but treatments differ (treatment to reduce gas generation in Regionalized 1 versus treatment to LDRs in the other three alternatives). As previously noted, the programwide risks of cancer fatalities, cancer incidence, and genetic effects from radiation exposure associated with treatment of RH-TRUW to LDRs (in the Regionalized 2, 3, and Centralized Alternatives) are approximately 3 orders of magnitude greater for the offsite and noninvolved worker populations and MEIs than the risks from treatment to minimize gas generation in Regionalized 1.

The offsite and noninvolved worker MEI hazard indices associated with treatment of RH-TRUW to LDRs are approximately 1 order of magnitude higher than in Regionalized 1. This trend reflects the potential for higher individual exposure to noncarcinogenic hazardous chemicals when RH-TRUW undergoes treatment to meet LDRs rather than to reduce gas generation. However, in all alternatives, exposures to noncarcinogenic, hazardous chemicals yield hazard indices well below 1.0, indicating a very low probability of adverse effects from these contaminants.

The programwide risks to workers from radionuclide exposure are more than 1 order of magnitude higher in the alternatives involving treatment to LDRs than in Regionalized 1. However, the risk of chemical-related cancer incidence is similar between alternatives.

D.3.4.7.4 *Summary*

In summary, the No Action Alternative presents the fewest health risk to all populations. Health risks generally increase for the public receptors as more extensive treatment of RH-TRUW is employed. Radionuclide- and construction/operational-related health risks to workers increase somewhat as more extensive treatment is employed. Chemical-related risks for all receptors are slightly higher in the alternatives that involve treatment (all except No Action) than in No Action, but are relatively independent of treatment type.

The primary risk drivers for the offsite and noninvolved worker populations are radiation exposure (as opposed to chemical exposure) and treatment option. For workers, the primary risk drivers are the size of the waste load and the person-hours necessary to process it.

D.3.4.8 Summary of Alternatives for Potential CH-TRUW Accidents

The following CH-TRUW alternatives were evaluated for potential treatment facility (incinerator) accidents: Regionalized 2, Regionalized 3, and Centralized. No storage accidents were analyzed. Health risks associated with accidental releases of radionuclides were analyzed, while health risks associated with accidental releases of chemicals were not analyzed. The types of accidents evaluated were (1) an incinerator explosion and resulting fire; (2) a baghouse area fire; and (3) an earthquake and resulting fire.

D.3.4.9 Special Assumptions and Considerations Used in the CH-TRUW Accident Analysis

All accidental releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops only to 99.9%. In the assessment of worker risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intra-facility source term for this accident is, therefore, 1,000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations.

Incineration accidents are assumed to cause releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene. During all accidents, one shift of waste management workers is assumed to be inside the incinerator facility. Shift size varies from 2 to 14 workers.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.7.1). However, the probability of occurrence is not directly taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. Estimated annual frequencies vary by accident type, installation location, and contaminant type. For radionuclide-related accidents, the incinerator explosion is considered to be "anticipated" (greater than 1E-02 per year); the baghouse area fire is considered "unlikely" (1E-4 to 1E-02 per year); and the earthquake with subsequent fire is considered "very unlikely" (1E-06 to 1E-04 per year).

D.3.4.10 Results Tables for the Risk Analysis of Potential CH-TRUW Accidents

Table D.3.4-35 presents a summary of the maximum reasonably foreseeable accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.4-36 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.4-37 through D.3.4-45 present more detailed results by health endpoint and installation.

Table D.3.4–35. Radionuclide-Related Risks from Potential Maximum Reasonably Foreseeable CH-TRUW Treatment Facility Accidents, by Alternative and Site

	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI[a]		Worker Population	
Site	CF[b]	CI[c]	CF	CI	CF	CI	CF	CI	CF	CI
Regionalized 2										
HS	2.1E+00	7.0E+00	4.9E-05	1.7E-04	4.0E-01	1.4E+00	4.0E-03	1.4E-02	5.5E+00	1.9E+01
INEL	3.0E-01	1.0E+00	3.4E-05	1.2E-04	4.3E-01	1.5E+00	2.6E-04	8.7E-04	1.9E+01	6.7E+01
LANL	2.8E+00	9.6E+00	1.3E-03	4.5E-03	8.0E-01	2.7E+00	2.4E-03	8.1E-03	2.7E+01	9.4E+01
RFP	1.9E+00	6.3E+00	6.6E-05	2.2E-04	2.7E-01	9.3E-01	8.1E-04	2.8E-03	1.4E+00	4.8E+00
SRS	8.0E-03	2.7E-02	2.5E-07	8.4E-07	1.8E-03	6.1E-03	7.7E-06	2.6E-05	1.6E-02	5.6E-02
Regionalized 3										
HS	2.1E+00	7.0E+00	4.9E-05	1.7E-04	4.0E-01	1.4E+00	4.0E-03	1.4E-02	5.5E+00	1.9E+01
INEL	7.3E-01	2.5E+00	8.3E-05	2.8E-04	1.1E+00	3.7E+00	6.6E-04	2.2E-03	5.8E+01	2.0E+02
SRS	8.0E-03	2.7E-02	2.5E-07	8.4E-07	1.8E-03	6.1E-03	7.7E-06	2.6E-05	1.6E-02	5.6E-02
Centralized										
WIPP	7.4E+00	2.5E+01	6.2E-02	2.1E-01	1.9E+00	6.3E+00	5.7E-02	2.0E-01	7.1E+01	2.5E+02

[a]MEI--most-exposed individual; each value represents the highest single risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b]CF--risk of cancer fatality associated with exposure to radionuclides.
[c]CI--risk of cancer incidence associated with exposure to radionuclides.

Table D.3.4–36. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential CH-TRUW Treatment Accidents, by Site

Site	Offsite Population	Noninvolved Worker Population	WM Worker Population		
			Regionalized 2	Regionalized 3	Centralized
Hanford	377,645	8,674	9	9	
INEL	153,106	8,451	11	13	
LANL	159,152	11,552	11		
RFP	2,171,877	6,993	5		
SRS	620,618	15,996	2	2	
WIPP	99,889	1060			14

Table D.3.4-37. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at Hanford Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	2.1E+00	4.9E-05	3.0E-01	7.0E+00	1.7E-04	1.1E+00
Incineration, (U) Baghouse Area Fire	8.0E-03	1.9E-07	1.2E-03	2.7E-02	6.5E-07	4.1E-03
Incineration, (A) Incinerator Explosion	3.8E-02	8.9E-07	5.5E+00	1.3E-01	3.0E-06	9.0E+00
Maximum reasonably foreseeable accident	2.1E+00	4.9E-05	5.5E+00	7.0E+00	1.7E-04	9.0E+00

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure..
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-06).

Table D.3.4-38. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at INEL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	3.0E-01	3.4E-05	1.0E+00	1.0E+00	1.2E-04	3.7E+00
Incineration, (U) Baghouse Area Fire	1.2E-03	1.3E-07	4.1E-03	4.0E-03	4.6E-07	1.4E-02
Incineration, (A) Incinerator Explosion	5.5E-03	6.2E-07	1.1E+01	1.9E-02	2.1E-06	1.1E+01
Maximum reasonably foreseeable accident	3.0E-01	3.4E-05	1.1E+01	1.0E+00	1.2E-04	1.1E+01

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-06).

Table D.3.4–39. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at LANL Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	2.8E+00	1.3E–03	1.5E+00	9.6E+00	4.5E–03	5.1E+00
Incineration, (U) Baghouse Area Fire	1.1E–02	5.2E–06	5.8E–03	3.8E–02	1.8E–05	2.0E–02
Incineration, (A) Incinerator Explosion	5.2E–02	2.4E–05	1.1E+01	1.8E–01	8.3E–05	1.1E+01
Maximum reasonably foreseeable accident	2.8E+00	1.3E–03	1.1E+01	9.6E+00	4.5E–03	1.1E+01

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

Table D.3.4–40. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at RFETS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	1.9E+00	6.6E–05	7.5E–02	6.3E+00	2.2E–04	2.6E–01
Incineration, (U) Baghouse Area Fire	7.3E–03	2.6E–07	3.0E–04	2.5E–02	8.8E–07	1.0E–03
Incineration, (A) Incinerator Explosion	3.4E–02	1.2E–06	1.4E+00	1.2E–01	4.1E–06	4.8E+00
Maximum reasonably foreseeable accident	1.9E+00	6.6E–05	1.4E+00	6.3E+00	2.2E–04	4.8E+00

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

Table D.3.4–41. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at SRS Under the Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	8.0E-03	2.5E-07	8.7E-04	2.7E-02	8.4E-07	3.1E-03
Incineration, (U) Baghouse Area Fire	3.2E-05	9.8E-10	3.4E-06	1.1E-04	3.3E-09	1.2E-05
Incineration, (A) Incinerator Explosion	1.5E-04	4.6E-09	1.6E-02	5.0E-04	1.6E-08	5.6E-02
Maximum reasonably foreseeable accident	8.0E-03	2.5E-07	1.6E-02	2.7E-02	8.4E-07	5.6E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (< 1E–06).

Table D.3.4–42. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at Hanford Under the Regionalized Alternative 3, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	2.1E+00	4.9E-05	3.0E-01	7.0E+00	1.7E-04	1.1E+00
Incineration, (U) Baghouse Area Fire	8.1E-03	1.9E-07	1.2E-03	2.7E-02	6.5E-07	4.1E-03
Incineration, (A) Incinerator Explosion	3.8E-02	8.9E-07	5.5E+00	1.3E-01	3.0E-06	9.0E+00
Maximum reasonably foreseeable accident	2.1E+00	4.9E-05	5.5E+00	7.0E+00	1.7E-04	9.0E+00

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (< 1E–06).

Table D.3.4-43. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at INEL Under Regionalized Alternative 3, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	7.3E-01	8.3E-05	3.2E+00	2.5E+00	2.8E-04	1.1E+01
Incineration, (U) Baghouse Area Fire	2.9E-03	3.3E-07	1.2E-02	9.8E-03	1.1E-06	4.3E-02
Incineration, (A) Incinerator Explosion	1.3E-02	1.5E-06	1.3E+01	4.6E-02	5.2E-06	1.3E+01
Maximum reasonably foreseeable accident	7.3E-01	8.3E-05	1.3E+01	2.5E+00	2.8E-04	1.3E+01

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-06).

Table D.3.4-44. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at SRS Under Regionalized Alternative 3, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	8.0E-03	2.5E-07	8.7E-04	2.7E-02	8.4E-07	3.1E-03
Incineration, (U) Baghouse Area Fire	3.2E-05	9.8E-10	3.4E-06	1.1E-04	3.3E-09	1.2E-05
Incineration, (A) Incinerator Explosion	1.5E-04	4.6E-09	1.6E-02	5.0E-04	1.6E-08	5.6E-02
Maximum reasonably foreseeable accident	8.0E-03	2.5E-07	1.6E-02	2.7E-02	8.4E-07	5.6E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (<1E-06).

Table D.3.4–45. Radionuclide-Related Accident Risks Associated With CH-TRUW Treatment at WIPP Under the Centralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	7.4E+00	6.2E-02	3.9E+00	2.5E+01	2.1E-01	1.4E+01
Incineration, (U) Baghouse Area Fire	2.9E-02	2.5E-04	1.5E-02	9.8E-02	8.3E-04	5.3E-02
Incineration, (A) Incinerator Explosion	1.4E-01	1.1E-03	1.4E+01	4.6E-01	3.9E-03	1.4E+01
Maximum reasonably foreseeable accident	7.4E+00	6.2E-02	1.4E+01	2.5E+01	2.1E-01	1.4E+01

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (< 1E–06).

D.3.4.11 Summary of the CH-TRUW Accident Analysis Results

For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors except the waste management worker is the earthquake with subsequent fire. For waste management workers, the dominant accident type is the incineration explosion.The highest installation-specific cancer fatality risks are associated with LANL and Hanford for all receptors in Regionalized 2 and Regionalized 3. For Centralized alternative, the highest installation-specific cancer fatality risks are associated with WIPP. Cancer fatality risks associated with operational incineration accidents such as the incineration explosion and baghouse area fire in alpha facilities are generally lower than those associated with similar accidents caused by an earthquake by 1 to 3 orders of magnitude for all receptors except waste management workers in all alternatives. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

D.3.4.11.1 *Risks to the Offsite Population from CH-TRUW Accidents*

For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks to the offsite population range from 8.0E-03 to 7.4 in population sizes ranging from 99,889 to 620,618. Cancer fatality risks from operational accidents range from 3.2E-05 to 1.4E-01 in population sizes ranging from 99,889 to 620,618. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to offsite populations is the earthquake with subsequent fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are approximately 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given installation. However, the estimated annual frequency of the earthquake scenario affecting the incinerator facility is "very unlikely" (1E-06 to 1E-04 per year) for all installations and alternatives, while the baghouse area fire and incinerator explosion are considered "unlikely" (1E-04 to 1E-02 per year) and "anticipated" (greater than 1E-02 per year), respectively.

LANL and Hanford have the highest cancer fatality risks to the offsite population from contact-handled alpha facility incineration accidents in Regionalized 2 because of relatively high releases of plutonium-238. For Regionalized 3, Hanford again has the highest cancer fatality risks, while WIPP is the highest cancer risk installation for Centralized. The highest cancer fatality risk at WIPP is 7.4 (distributed over a population of 99,889) for the earthquake scenario in the Centralized Alternative. LANL and Hanford have the next highest cancer fatality risks to the offsite population from incineration accidents caused by an earthquake (2.8 distributed over a population of 159,152 and 2.1 distributed over a population of 377,645, respectively). The controlling contaminant at WIPP, LANL, and Hanford is plutonium-238. Internal exposure is the primary route for all three installations. For the incinerator explosion accident, cancer fatality risks are again highest at LANL for Regionalized 2, at Hanford for Regionalized 3, and at WIPP for the Centralized Alternative. The controlling contaminant at all three installations is plutonium-238; the primary exposure route is internal. The risks for radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities.

D.3.4.11.2 *Risks to the Noninvolved Worker Population from CH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the noninvolved worker population follow the trends for the offsite population, but vary slightly. For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks range from 1.8E-03 to 1.9 in population sizes ranging from 1,060 to 15,996. Cancer fatality risks from operational accidents range from 7.0E-06 to 3.4E-02 in population sizes ranging from 1,060 to 15,996. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to noninvolved worker populations is the earthquake with subsequent fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are generally 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given installation. Recall, however, that the estimated annual frequency of the earthquake scenario affecting the incinerator facility is the lowest of the three accident types.

For the facility earthquake scenario, LANL produces the greatest risk of cancer fatalities in Regionalized 2, INEL produces the greatest risk of cancer fatalities in Regionalized 3, while WIPP is the highest-risk installation in the Centralized alternative. The maximum reasonably foreseeable accident risks occur at WIPP (1.9 cancer fatalities over a population of 1060), followed by INEL (1.1 cancer fatalities over a population of 8451) and LANL (0.8 cancer fatalities over a population of 11,552). The controlling contaminant at LANL and WIPP is plutonium-238. At INEL both americium-241 and plutonium-238 are the controlling radionuclides. For operational accidents, the highest-risk installations are LANL in Regionalized 2, INEL in Regionalized 3, and WIPP in the Centralized alternative. In these alternatives, cancer fatality risk associated with the worst-case incinerator accident (incinerator explosion) is 1.5E-02 for LANL in a population of 11,552, 2.0E-02 for INEL in a population of 8,451, and 3.4E-02 for WIPP in a population of 1060 . The controlling contaminants at INEL are americium-241 and plutonium-238. At both LANL and WIPP plutonium-238 is the controlling radionuclide.

D.3.4.11.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from CH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the offsite MEI and noninvolved worker MEI generally follow those for their respective populations. Incineration accident risks at a given installation do not differ greatly among alternatives. Risks to the MEIs associated with a particular accident either remain the same at an installation across alternatives or increase only slightly with waste consolidation. Differences in cancer risks between earthquake accidents and internally-initiated accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake with subsequent fire by approximately two order of magnitude. The highest-risk installations for the offsite MEI differ somewhat from those observed for the offsite population. The highest installation-specific cancer fatality risk to the offsite MEI is from the earthquake scenario at LANL (1.3E-03) in Regionalized 2, INEL (8.3E-05) in Regionalized 3, and WIPP (6.2E-02) in the Centralized alternative. The next highest installation risks for the same earthquake scenario are at RFETS in Regionalized 2 (6.6E-05) and Hanford in Regionalized 3 (4.9E-05). In each alternative, the risks of cancer fatalities to the offsite MEI for other incinerator accidents are approximately 1 to 3 orders of magnitude lower than those for the earthquake scenario. For the

incinerator explosion accident, cancer risks to the offsite MEI are greatest at LANL (2.4E-05) in Regionalized 2, INEL (1.5E-06) in Regionalized 3, and WIPP (1.1E-03) in the Centralized Alternative.

The highest installation-specific cancer fatality risk to the noninvolved worker MEI is from the earthquake scenario at Hanford in Regionalized 2 and 3, and at WIPP in Centralized (ranging from 4.0E-03 to 5.7E-02). The next highest risk to the noninvolved worker MEI is from the same earthquake scenario at LANL in Regionalized 2 and INEL in Regionalized 3 (2.4E-03 and 6.6E-04 cancer fatalities, respectively). For the maximum reasonably foreseeable operational accident (incinerator explosion) the highest-risk installation for the noninvolved worker MEI is Hanford in Regionalized 2 and 3, and at WIPP in Centralized (ranging from 7.3E-05 to 1.1E-03).

D.3.4.11.4 *Risks to Waste Management Workers from CH-TRUW Accidents*

For incineration accidents involving releases of radionuclides, installation-specific worker risks are similar among alternatives, increasing only very slightly at installations where CH-TRUW is consolidated for treatment. Unlike all other receptors, the highest cancer-fatality risks to the waste management worker occur during the incinerator explosion accident. Estimated worker cancer fatalities associated with the incinerator explosion accident range from 1.6E-02 to 1.4E+01. For the earthquake accident, estimated worker cancer fatalities range from 8.7E-04 to 3.9. Shift size varies from 2 to 14 workers. In all alternatives, the incinerator explosion scenario produces the higher worker risks by about 1 to 2 orders of magnitude over the earthquake scenario and about 3 to 4 orders of magnitude over the baghouse area fire scenario.

The highest installation-specific cancer fatality risks associated with the incinerator accidents are for the incinerator explosion accident at LANL in Regionalized 2 (1.1E+01), at INEL in Regionalized 3 (1.3E+01), and at WIPP in Centralized (1.4E+01). For the earthquake facility incinerator accident, the highest installation cancer fatality risks are at LANL (1.5) in Regionalized 2, at INEL (3.2) in Regionalized 3, and WIPP in Centralized (3.9).

D.3.4.12 Summary of Alternatives for Potential RH-TRUW Accidents

The following RH-TRUW alternatives were evaluated for potential treatment facility (incinerator) accidents: Regionalized 2, Regionalized 3, and Centralized. All three of these alternatives treat to RCRA LDRs and store at 2 installations. Thus all accident scenarios remain the same across alternatives. No storage accidents were analyzed for RH-TRUW. Health risks associated with accidental releases of radionuclides were analyzed, while health risks associated with accidental releases of chemicals were not analyzed. The types of treatment facility accidents evaluated were (1) an incinerator explosion and resulting fire; (2) a baghouse area fire; and (3) an earthquake with subsequent fire.

D.3.4.13 Results Tables for the Risk Analysis of Potential RH-TRUW Accidents

Table D.3.4-46 presents a summary of the maximum reasonably foreseeable accident risks to the offsite and noninvolved worker populations, their respective MEIs, and waste management worker populations for treatment facility accidents, by installation and alternative. Table D.3.4-47 provides the sizes of the offsite, noninvolved worker, and worker populations at each installation. Tables D.3.4-48 through D.3.4-49 present more detailed results by health endpoint and installation.

Table D.3.4-46. Radionuclide-Related Risks from Potential Maximum Reasonably Foreseeable RH-TRUW Treatment Facility Accidents, by Alternative and Site

Site	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI[a]		Worker Population	
	CF[b]	CI[c]	CF	CI	CF	CI	CF	CI	CF	CI
Regionalized 2, 3, and Centralized										
HS	9.7E-03	3.3E-02	2.3E-07	7.7E-07	1.5E-03	4.9E-03	1.5E-05	4.9E-05	2.2E-03	7.8E-03
ORNL	1.2E-01	4.1E-01	1.0E-05	3.5E-05	4.6E-02	1.6E-01	5.1E-05	1.8E-04	8.9E-02	3.1E-01

[a] MEI=most-exposed individual; each value represents the highest single risk (not the sum of all risks) to the MEI from among all accidents at an installation.
[b] CF=risk of cancer fatality associated with exposure to radionuclides.
[c] CI=risk of cancer incidence associated with exposure to radionuclides.

Table D.3.4–47. Sizes of the Offsite, Noninvolved Worker, and Worker Populations Affected by Risks from Potential RH-TRUW Treatment Accidents, by Site

Site	Offsite Population	Noninvolved Worker Population	WM Worker Population		
			Regionalized 2	Regionalized 3	Centralized
Hanford	377,645	8,674	1	1	1
ORR	881,652	3,809	7	7	7

Table D.3.4–48. Radionuclide-Related Accident Risks Associated With RH-TRUW Treatment at Hanford Under the Regionalized Alternative 2, 3, and Centralized Alternatives, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	9.7E–03	2.3E–07	1.2E–04	3.3E–02	7.7E–07	4.3E–04
Remote Incineration, (U) Baghouse Area Fire	3.8E–05	8.9E–10	4.8E–07	1.3E–04	3.0E–09	1.7E–06
Remote Incineration, (A) Incinerator Explosion	1.8E–04	4.2E–09	2.2E–03	6.1E–04	1.4E–08	7.8E–03
Maximum reasonably foreseeable accident	9.7E–03	2.3E–07	2.2E–03	3.3E–02	7.7E–07	7.8E–03

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (>1E–2), "U" for unlikely (1E–4 to 1E–2), "VU" for very unlikely (1E–6 to 1E–4), and "EU" for extremely unlikely (<1E–06).

Table D.3.4-49. Radionuclide-Related Accident Risks Associated With RH-TRUW Treatment at ORNL Under the Regionalized Alternative 2, 3, and Centralized Alternatives, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Population[c]	MEI	Workers	Population[c]	MEI	Workers
Incineration, (VU)[d] Earthquake	1.2E-01	1.0E-05	4.8E-03	4.1E-01	3.5E-05	1.7E-02
Remote Incineration, (U) Baghouse Area Fire	4.7E-04	4.0E-08	1.9E-05	1.6E-03	1.4E-07	6.6E-05
Remote Incineration, (A) Incinerator Explosion	2.2E-03	1.9E-07	8.9E-02	7.5E-03	6.4E-07	3.1E-01
Maximum reasonably foreseeable accident	1.2E-01	1.0E-05	8.9E-02	4.1E-01	3.5E-05	3.1E-01

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Offsite.
[d] Accident annual frequency codes are "A" for anticipated (> 1E-2), "U" for unlikely (1E-4 to 1E-2), "VU" for very unlikely (1E-6 to 1E-4), and "EU" for extremely unlikely (< 1E-06).

D.3.4.14 Summary of the RH-TRUW Accident Analysis Results

In general, the overall risks associated with managing RH-TRUW are somewhat lower than the risks from managing CH-TRUW. For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors except the waste management worker is the earthquake and resulting fire. For waste management workers, the dominant accident type is the incineration explosion.The highest installation-specific cancer fatality risks are associated with ORR for all receptors in all alternatives (Regionalized 2, 3 and Centralized). Cancer fatality risks associated with incineration accidents in remote facilities are generally lower than those associated with similar accidents caused by an earthquake by 2 to 3 orders of magnitude for all receptors (except waste management workers) in all alternatives. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

D.3.4.14.1 *Risks to the Offsite Population from RH-TRUW Accidents*

For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks to the offsite population range from 9.7E-03 to 1.2E-01 in population sizes ranging from 377,645 to 881,652.

Cancer fatality risks from internally-initiated accidents range from 3.8E-05 to 2.2E-03 in population sizes ranging from 377,645 to 881,652. Incineration accident risks at a given site do not differ among alternatives. Risks associated with a particular accident remain the same at a site across all alternatives.

The incineration accident type resulting in the highest risks to offsite populations is the earthquake with subsequent fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are approximately 1 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given site. However, the estimated annual frequency of the earthquake scenario affecting the incinerator facility is "very unlikely" (1E-06 to 1E-04 per year) for all sites and alternatives, while the baghouse fire and incinerator explosion are considered "unlikely" (1E-04 to 1E-02 per year) and "anticipated" (greater than 1E-02 per year), respectively.

ORR has the highest cancer fatality risks to the offsite population from remote-handled alpha facility incineration accidents in all alternatives (Regionalized 2, Regionalized 3, and Centralized) because of relatively high releases of curium-244. Cancer fatalities of 2.2E-03 over a population of 881,652 are estimated to occur at ORR for the incinerator explosion. For the earthquake scenario, ORR once again has the highest cancer fatality risks with 1.2E-01 over a population of 881,652. Hanford is always the second highest cancer fatality site in all three alternatives by one to two orders of magnitude.The controlling contaminant at ORR is curium-244. Internal exposure is the primary route. The controlling contaminant at Hanford is plutonium-239; the primary exposure route is internal. The risks of radionuclide-related cancer incidence and genetic effects follow the same general trend as for cancer fatalities.

D.3.4.14.2 *Risks to the Noninvolved Worker Population from RH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the noninvolved worker population follow the trends for the offsite population. For incineration accidents involving releases of radionuclides due to an earthquake, cancer fatality risks range from 1.5E-03 to 4.6E-02 in population sizes ranging from 3,809 to 8,674. Cancer fatality risks from operational accidents range from 5.7E-06 to 8.5E-04 in population sizes ranging from 3,809 to 8,674. Incineration accident risks at a given installation do not differ among alternatives. Risks associated with a particular accident remain the same at a site across all alternatives.

The incineration accident type resulting in the highest risks to noninvolved worker populations is the earthquake with subsequent fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and baghouse area fire) are approximately 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given site. Recall, however, that the estimated annual frequency of the earthquake scenario affecting the incinerator facility is the lowest of the three accident types.

For the facility earthquake scenario, ORR produces the greatest risk of cancer fatalities in all alternatives (Regionalized 2, Regionalized 3, and Centralized). The worst-case accident risks occur during the facility earthquake scenario at ORR with 4.6E-02 cancer fatalities over a population of 3,809, followed by Hanford with 1.5E-03 cancer fatalities over a population of 8,674. For operational accidents, the highest-risk site is once again ORR for all alternatives, followed by Hanford. In these alternatives, cancer fatality risk associated with the worst-case incinerator accident (incinerator explosion) is 8.5E-04 for ORR in a population of 3,809, and 2.7E-05 for Hanford in a population of 8,674.

D.3.4.14.3 *Risks to the Most-Exposed Noninvolved Worker and Most-Exposed Offsite Individual from RH-TRUW Accidents*

For radionuclide-related accidents, the trends in risk to the offsite MEI and noninvolved worker MEI generally follow those for their respective populations. Incineration accident risks at a given site do not differ among alternatives. Risks to the MEIs associated with a particular accident remain the same at an installation across all alternatives. Differences in cancer risks between earthquake facility incineration accidents and internally-initiated facility incineration accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake with subsequent fire. The highest site-specific cancer fatality risk to the offsite MEI is from the facility earthquake scenario at ORR for all alternatives (Regionalized 2, Regionalized 3, and Centralized). Estimated cancer fatality risks to the offsite MEI at ORR are 1.0E-05. The next highest site risks are for the same facility earthquake scenarios at Hanford for all alternatives (2.3E-07). For the operational accidents of which the incinerator explosion is the worst-case accident, cancer fatality risks to the offsite MEI are once again greatest at ORR (1.9E-07)

for all alternatives. Hanford has the next highest risk with 4.2E-09 estimated cancer fatalities for all alternatives.

The risks to the noninvolved worker MEI follows the same trends in risk as those to the offsite MEI. The earthquake scenario at ORR is the worst-case accident for the noninvolved worker MEI for all alternatives. Estimated cancer fatality risks to the noninvolved worker MEI at ORR is 5.1E-05. Hanford has the next highest risk with 1.5E-05 estimated cancer fatalities for the same type of accident. For the operational accidents of which the incinerator explosion is the worst-case accident, ORR is once again the highest site-specific cancer fatality risk with 9.4E-07 estimated cancer fatalities. Hanford has the next highest risk with 2.7E-07 estimated cancer fatalities for the incinerator explosion.

D.3.4.14.4 *Risks to Waste Management Workers from RH-TRUW Accidents*

For incineration accidents involving releases of radionuclides, site-specific worker risks are the same among alternatives. Unlike all other receptors, the highest cancer-fatality risks to the waste management worker occur during the incinerator explosion accident. Estimated worker cancer fatalities associated with the earthquake facility incineration accident range from 1.2E-04 to 4.8E-03. For operational accident scenarios, estimated worker cancer fatalities range from 4.8E-07 to 8.9E-02. Shift size varies from 1 to 7 workers. In all alternatives, the incinerator explosion scenario produces the higher worker risks by about 1 order of magnitude over the earthquake scenario and about 3 to 4 orders of magnitude over the baghouse area fire scenario.

The highest site-specific cancer fatality risks associated with the incinerator accidents are for the incinerator explosion at ORR with 8.9E-02 estimated cancer fatalities. Hanford has 2.2E-03 estimated cancer fatalities for this same type of accident. For the earthquake scenario accident, ORR once again has the highest site cancer fatality risks followed by Hanford (4.8E-03 and 2.3E-07, respectively).

D.3.5 Low-Level Mixed Waste

Low-level mixed waste (LLMW) is waste that contains both low-level radioactivity and hazardous components regulated under the Resource Conservation and Recovery Act in sufficient quantities to render the waste hazardous per the guidelines of 40 CFR 261. Although asbestos-containing wastes are not considered hazardous under the Resource Conservation and Recovery Act, friable asbestos waste is considered a hazardous waste in several states. For the purposes of the PEIS, low-level radioactive waste contaminated with asbestos is considered LLMW. High-level waste, transuranic waste, or spent nuclear fuel that may be contaminated with hazardous components regulated by the Resource Conservation and Recovery Act are not classified as LLMW and are not evaluated for human health risks in this portion of the appendix (high-level waste is considered in Section D.3.1 and transuranic wastes containing hazardous constituents are addressed in Section D.3.4).

Like low-level waste, LLMW may contain a wide range of radionuclides at activities ranging from trace amounts to thousands of curies. Packaged LLMW with a surface dose rate of less than 200 mrem/h is categorized as contact-handled LLMW (CH-LLMW). Packaged LLMW with a surface dose rate greater than 200 mrem/h emits sufficient penetrating beta, gamma, or neutron radiation to require remote handling, and is classified as remote-handled LLMW (RH-LLMW). The handling category determines the level of protective shielding needed to store and process the waste safely. The distinction between CH-LLMW and RH-LLMW is maintained in the human health risk analyses for both routine operations and accidents. The risks associated with each category are estimated and discussed separately.

LLMW is also categorized according to its content of alpha-emitting radionuclides (e.g., alpha LLMW or nonalpha LLMW) and polychlorinated biphenyls (PCBs) (e.g., PCB LLMW or non-PCB LLMW).

About 50 sites within the DOE complex generate LLMW, including those listed below (note that the abbreviations given here are used in the tables in this appendix):

- Argonne National Laboratory–East (ANL–E), Argonne, Illinois
- Brookhaven National Laboratory (BNL), Brookhaven, New York
- Fernald Environmental Management Project (FEMP), Fernald, Ohio
- Hanford Site (Hanford), Richland, Washington
- Idaho National Engineering Laboratory (INEL), Idaho Falls, Idaho
- Inhalation Toxicology Research Institute (ITRI), Albuquerque, New Mexico

- Kansas City Plant (KCP), Kansas City, Missouri
- Knolls Atomic Power Laboratory–Kesselring (KAPL–K), Schenectady, New York
- Lawrence Berkeley Laboratory (LBL), Berkeley, California
- Lawrence Livermore National Laboratory (LLNL), Livermore, California
- Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
- Mound Plant (Mound), Miamisburg, Ohio
- Nevada Test Site (NTS), Las Vegas, Nevada
- Oak Ridge Reservation (ORR), Oak Ridge, Tennessee
- Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky
- Pantex Plant (Pantex), Amarillo, Texas
- Portsmouth Gaseous Diffusion Plant (PORTS), Piketon, Ohio
- Rocky Flats Environmental Technology Site (RFETS), Golden, Colorado
- Sandia National Laboratories–New Mexico (SNL-NM), Albuquerque, New Mexico
- Savannah River Site (SRS), Aiken, South Carolina
- West Valley Demonstration Project (WVDP), West Valley, New York

This list includes the 16 major sites considered for LLMW management described in Section 1.6.1 and Chapter 6 of Volume I.

Treatment risks were also estimated separately later in this section in Tables D.3.5–15 through D.3.5–21 for several other sites in addition to the 16 major sites. These sites include KAPL-K, LBL, Mound, and KCP. Treatment risks at these sites are contained in the programwide risk tables presented in this section (Tables D.3.5–7 through D.3.5–14) and in the alternative summary risk tables presented in Section 6.4 of Volume I.

Depending on its chemical and physical properties, LLMW can be grouped into waste stream categories according to the type of treatment needed, such as aqueous wastes, organic liquids, inorganic or organic sludges, contaminated soil with or without debris, or special wastes.

Chapters 3 and 6 of the PEIS and the LLMW technical report (ANL, 1996e) provide more detailed information on this waste, including LLMW inventories at DOE sites, estimated release rates, treatment categories used in the PEIS, considerations regarding disposal, and the process for developing PEIS LLMW alternatives.

D.3.5.1 Summary of LLMW Alternatives

The PEIS waste management alternatives (No Action, Decentralized, Regionalized, and Centralized) and the rationale for developing the various LLMW analysis alternatives are discussed rigorously in the main body of the PEIS. A broad range of Decentralized, Regionalized, and Centralized Alternatives are analyzed for this waste stream:

- The No Action Alternative: In this alternative, all sites treat CH-LLMW and RH-LLMW using existing capabilities and store the treated waste onsite (there is no disposal scenario for this alternative).
- The Decentralized Alternative: In this alternative, 49 sites treat CH-LLMW and 15 sites dispose of it.
- The Regionalized Alternatives: Regionalized 1 involves treatment of CH-LLMW at 11 sites and disposal at 12. In Regionalized 2 and 3, CH-LLMW is treated at seven sites and disposed of at six and one site(s), respectively. Regionalized 4 entails treating CH-LLMW at four sites and disposing of it at six.
- The Centralized Alternative: Hanford treats and disposes of CH-LLMW in this alternative.
- The RH-LLMW management scenario (for all alternatives except No Action): four sites treat this waste and dispose of it onsite.

This series of alternatives makes it possible to compare the relative risks of consolidating CH-LLMW and treating it at varying numbers of sites, and the risks associated with a broad range of disposal configurations.

Table D.3.5–1 depicts the overall treatment and storage schemes for the LLMW alternatives; detailed information on waste consolidation scenarios can be found in the LLMW technical report (ANL, 1996e). Note that for the purposes of this risk analysis, the waste load from the ITRI has been added to the waste load for SNL-NM.

D.3.5.2 Special Assumptions and Considerations Used in the LLMW Risk Analysis

The following chemicals were used as representatives of generic classes of chemical contaminants in the risk evaluation for the offsite and noninvolved worker populations: 1,2-dichloroethane (to represent compounds containing two chlorine atoms), 1,1,1-trichloroethane (to represent compounds containing three chlorine atoms), carbon tetrachloride (to represent compounds containing four chlorine atoms),

Table D.3.5–1. PEIS Alternatives for LLMW

Alternative	Scenario	ANL-E	FEMP	Hanford	INEL	LANL	LLNL	NTS	ORR	Pantex	PGDP	PORTS	RFETS	SNL-NM	SRS	WVDP	BNL	LBL	Mound	KCP	KAPL-K
No Action (CH and RH) All installations treat using existing capabilities and store onsite	Treat at all	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	Store at all	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Decentralized CH treatment	CH treatment at 49	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
	Dispose at 15	D	D	D	D	D	D	D	D	D	D	D	D	D	D		D				
Regionalized 1 CH treatment	CH treatment at 11		T	T	T	T	T		T	T	T	T	T		T						
	Dispose at 12		D	D	D	D	D	D	D	D	D	D	D		D						
Regionalized 2 CH treatment	CH treatment at 7			T	T	T			T			T	T		T						
	Dispose at 6			D	D	D		D	D						D						
Regionalized 3 CH treatment	CH treatment at 7			T	T	T			T			T	T		T						
	Dispose at 1							D													
Regionalized 4 CH treatment	CH treatment at 4			T	T				T						T						
	Dispose at 6			D	D	D		D	D						D						
Centralized CH treatment	CH treatment at 1			T																	
	Dispose at 1			D																	
(All alternatives except No Action) RH treatment	RH treatment at 4			T	T				T						T						
	Dispose at 4			D	D				D						D						

Notes: T = treatment site; S = storage site; D = disposal site.

1,2,2-trichloro-1,1,2-trifluoroethane (to represent chlorofluorocarbons), benzene (to represent water-insoluble organic compounds), and acetone (to represent water-soluble organic compounds). It was also assumed that any chromium in the source term was the inhalation carcinogen, chromium (VI) (100%), due to lack of better information. This is a conservative assumption, and health risks associated with chromium (VI) may be overestimated.

For all disposal scenarios, it is assumed that shallow land burial will be used at sites west of the Mississippi River and tumulus (above-ground vault) disposal will be used at eastern sites. The exceptions are RFETS, which disposes in tumulus vaults, and SRS, which disposes in below-ground vaults.

It is assumed that, except in the No Action Alternative, LLMW disposal capacity at each site will be expanded as required to meet disposal demands.

The waste containers for CH-LLMW are assumed to be 55-gal drums; RH-LLMW is assumed to be packaged in concrete casks with 6-in. walls.

For the purposes of estimating the human health risks associated with treatment and disposal of LLMW, no distinction is made between PCB-contaminated LLMW and non-PCB LLMW. If a site is postulated to possess PCB-LLMW, the source term for that mixed waste is combined with all the other LLMW source terms for that site.

D.3.5.3 Results Tables for the LLMW Human Health Risk Analysis

This section contains the results tables for the LLMW human health risk analysis. A discussion of the results is presented in Section D.3.5.4. The risk numbers in the tables are displayed in the standard exponential notation used in risk assessment; directions on reading this notation and a more complete description of the types of information in the tables are given in Section D.2.

- Table D.3.5–2 presents an overview, by alternative, of the *total*, programwide risks associated with treatment of LLMW. Included are the risks of cancer fatalities and cancer incidence for the offsite and noninvolved worker populations; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste treatment. This table provides the estimated *total number* of people in the three populations who will develop or die of

cancers caused by exposure to LLMW if a particular alternative is implemented nationwide. In addition, it shows the estimated total number of workers who will be killed during construction and operational activities. The results in this table are drawn from Tables D.3.5–7 through D.3.5–14 on the following pages.

- Table D.3.5–3 presents an overview, by alternative, of the programwide risks associated with disposal of LLMW. This table summarizes the risks of cancer fatalities and cancer incidence for the MEL of the hypothetical farm family; the likelihood of adverse health effects to the maximally exposed lifetime (MEL) from exposure to noncarcinogenic, hazardous chemicals; the total risks to members of all 143 lifetimes of the farm family; and the risks of cancer fatalities, cancer incidence, and construction and operational fatalities for waste management workers associated with waste disposal. The results in this table are drawn from Tables D.3.5–23 through D.3.5–29.
- Table D.3.5–4 shows the sizes of the total affected populations for each alternative.
- Table D.3.5–5 summarizes the risks to the noninvolved worker and offsite MEIs for each LLMW alternative. The numbers in this table are the estimated *probabilities* that the offsite and noninvolved worker MEIs will die of or develop cancer from radionuclide and chemical exposure and indicators of the likelihood of adverse health effects to the MEIs from exposure to noncarcinogenic, hazardous chemicals. These results are drawn from Tables D.3.5–7 through D.3.5–14 and Tables D.3.5–23 through D.3.5–29.
- Table D.3.5–6 lists the radionuclides that contribute most of the risk of cancer fatality to the offsite population for LLMW treatment, by site and alternative.

The following tables are located on the following pages:

- Tables D.3.5–7 through D.3.5–14 provide more detailed information on the programwide health risks to all receptors from treatment of LLMW, by alternative and health endpoint.
- Tables D.3.5–15 through D.3.5–22 present summaries of the health risks for the offsite and worker populations, by alternative and site.
- Tables D.3.5–23 through D.3.5–29 provide more detailed information on the programwide health risks to the MEL of the hypothetical farm family of four, all 143 lifetimes of the farm family, and waste disposal workers, by alternative and health endpoint.
- Tables D.3.5–30 through D.3.5–36 present summaries of the health risks to the farm family and workers and an indication of which farm family lifetime is maximally exposed, by installation.

Table D.3.5-2. Summary of Programwide Risks Associated With Treatment of LLMW: Risks to Total Populations, by Alternative

Alternative	Offsite Population		Noninvolved Worker Population		WM Workers		
	CF	CI	CF	CI	CF	CI	C&OF
No Action	2.8E-01	1.0	1.3E-02	4.4E-02	8.4E-01	2.9	1.7
Decentralized	1.7E-01	5.8E-01	2.4E-03	8.0E-03	5.2E-01	1.8	4.0
Regionalized 1	1.6E-01	5.5E-01	2.4E-03	8.0E-03	5.6E-01	2.0	3.7
Regionalized 2	1.8E-02	6.1E-02	3.6E-04	1.2E-03	5.7E-01	2.0	3.4
Regionalized 3	1.8E-02	6.1E-02	3.6E-04	1.2E-03	5.7E-01	2.0	3.4
Regionalized 4	1.8E-02	5.9E-02	3.6E-04	1.2E-03	6.2E-01	2.2	3.1
Centralized	2.5E-02	8.6E-02	3.3E-04	1.1E-03	6.3E-01	2.2	2.6
RH-LLMW	1.3E-03	4.5E-03	4.2E-05	1.4E-04	2.3E-02	8.1E-02	4.5E-01

Notes: CF = cancer fatality associated with radionuclide exposure; CI = cancer incidence associated with exposure to radionuclides and carcinogenic chemicals; C&OF = fatalities due to the physical hazards of constructing and operating waste management facilities.

Table D.3.5-3. Summary of Programwide Risks Associated With Disposal of LLMW: Risks to Hypothetical Farm Family and Waste Management Workers, by Alternative

Alternative	MEL of Farm Family				All (143) Lifetimes of Farm Family			WM Workers		
	CF	Rad CI	Chem CI	HI	CF	Rad CI	Chem CI	CF	CI	C&OF
Decentralized	1.5E-03	4.9E-03	9.8E-03	2.4	3.5E-02	1.2E-01	4.9E-01	5.5E-01	1.9	4.3E-01
Regionalized 1	1.2E-03	4.1E-03	9.8E-03	3.0	2.4E-02	8.0E-02	5.0E-01	5.5E-01	1.9	4.6E-01
Regionalized 2	1.4E-03	4.8E-03	1.3E-02	2.7	2.4E-02	8.0E-02	8.3E-01	5.2E-01	1.8	4.2E-01
Regionalized 3	0.00	0.00	7.2E-04	8.1E-01	0.00	0.00	3.0E-02	3.9E-01	1.4	8.4E-02
Regionalized 4	1.5E-03	5.1E-03	1.3E-02	2.7	2.5E-02	8.5E-02	8.2E-01	6.4E-01	2.2	4.1E-01
Centralized	1.9E-02	6.6E-02	9.5E-04	2.4	2.5E-01	8.6E-01	8.5E-03	3.6E-01	1.3	1.5E-01
RH-LLMW	8.5E-05	2.9E-04	1.4E-05	1.3E-02	1.3E-03	4.5E-03	5.8E-04	1.5E-03	5.2E-03	3.0E-02

Notes: CF = risk of cancer fatality associated with exposure to both radionuclides and carcinogenic chemicals; Rad CI = risk of cancer incidence associated with exposure to radionuclides; Chem CI = Risk of cancer incidence associated with exposure to chemical carcinogens; HI = hazard index; C&OF = estimated construction and operational fatalities from physical hazards.

Table D.3.5-4. Size of Total Offsite, Noninvolved Worker, and Worker Populations Affected by Risks From Routine Management of LLMW, by Alternative

Alternative	Offsite Population	Noninvolved Worker Population	WM Workers
No Action	53,223,046	113,878	10,261
Decentralized	53,223,046	113,878	13,070
Regionalized 1	53,223,046	113,878	12,867
Regionalized 2	53,223,046	113,878	12,467
Regionalized 3	53,223,046	113,878	12,467
Regionalized 4	53,223,046	113,878	11,261
Centralized	53,223,046	113,878	8,672
RH-LLMW	2,032,976	36,930	1,119

Table D.3.5-5. Summary of Programwide Risks Associated With Treatment of LLMW: Risks to the Offsite and Noninvolved Worker Maximally Exposed Individuals, by Alternative

	Offsite MEI				Noninvolved Worker MEI			
Alternative	CF	Rad CI	Chem CI	HI	CF	Rad CI	Chem CI	HI
No Action	3.5E-06	1.2E-05	2.0E-08	2.3E-05	8.7E-06	3.0E-05	2.1E-07	4.5E-05
Decentralized	2.5E-06	8.5E-06	1.2E-09	1.4E-06	7.3E-07	2.5E-06	7.1E-09	8.8E-06
Regionalized 1	2.6E-06	8.7E-06	1.0E-09	1.4E-06	7.4E-07	2.5E-06	6.2E-09	8.7E-06
Regionalized 2	2.7E-07	9.2E-07	1.0E-09	1.4E-06	3.1E-07	1.0E-06	6.2E-09	8.8E-06
Regionalized 3	2.7E-07	9.2E-07	1.0E-09	1.4E-06	3.1E-07	1.0E-06	6.2E-09	8.8E-06
Regionalized 4	2.7E-07	9.3E-07	1.5E-09	2.0E-06	3.1E-07	1.1E-06	9.3E-09	1.3E-05
Centralized	5.2E-07	1.8E-06	4.1E-10	4.5E-07	5.8E-07	2.0E-06	1.4E-08	1.6E-05
RH-LLMW	3.4E-08	1.2E-07	2.9E-12	4.8E-09	2.3E-08	7.8E-08	1.8E-11	3.8E-08

Notes: MEI = maximally exposed individual; CF = risk of cancer fatality associated with exposure to radionuclides; Rad CI = risk of cancer incidence associated with exposure to radionuclides; Chem CI = risk of cancer incidence associated with exposure to chemical carcinogens; HI = hazard index.

Table D.3.5–6. Radionuclide Contributing the Highest Risk of Cancer Fatality to the Offsite Population for LLMW Treatment, by Alternative and Site

Alt.	Site																			
	ANL-E	Hanford	INEL	KAPL-K	KCP	LANL	LBL	LLNL	NTS	ORR	Pantex	PORTS	PGDP	RFETS	SNL/NM	SRS	WVDP	FEMP	BNL	Mound
No Action	U-238[a] 1.24E-04[b]	Pu-238 1.11E-02	Pu-238 3.85E-04	Co-60 4.87E-04	Co-60 4.61E-06	Pu-238 8.81E-05	U-238 3.45E-05	Pu-238 7.55E-04	U-238 8.1E-05	U-238 1.09E-01	Pu-238 1.45E-06	U-238 5.92E-05	U-238 3.32E-03	Pu-238 1.63E-02	Pu-238 3.13E-05	H-3 2.60E-03	Pu-238 2.03E-04	U-238 5.90E-04	U-238 1.08E-04	Pu-238 1.38E-05
Dec.	U-238 7.1E-06	Pu-238 9.84E-04	H-3 3.50E-05	H-3 1.98E-04	H-3 2.30E-06	H-3 5.86E-04	H-3 1.02E-02	H-3 1.54E-01	U-238 1.1E-06	U-238 4.86E-04	H-3 3.41E-05	U-238 2.49E-06	U-238 1.10E-04	Pu-238 4.09E-05	H-3 1.30E-04	H-3 1.68E-03	Pu-238 1.08E-07	U-238 2.39E-05	U-238 5.32E-06	H-3 1.26E-04
Reg. 1	H-3 5.3E-07	Pu-238 9.03E-04	H-3 3.50E-05	Co-60 1.05E-07	Co-60 9.90E-10	H-3 6.02E-04	U-238 7.74E-09	H-3 1.57E-01	H-3 5.2E-09	U-238 4.19E-04	H-3 3.41E-05	H-3 3.03E-05	U-238 1.10E-04	Pu-238 4.08E-05	Pu-238 7.30E-09	H-3 1.68E-03	H-3 1.06E-07	U-238 3.30E-04	U-238 2.43E-08	Pu-238 3.22E-09
Reg. 2	H-3 5.3E-07	H-3 1.20E-02	H-3 6.10E-04	Co-60 1.05E-07	Co-60 9.90E-10	H-3 8.52E-04	U-238 7.74E-09	Pu-238 1.76E-07	H-3 5.2E-09	U-238 6.56E-04	H-3 2.34E-06	H-3 3.15E-05	U-238 7.48E-07	Pu-238 4.09E-05	Pu-238 7.30E-09	H-3 1.68E-03	H-3 1.06E-07	U-238 1.33E-07	U-238 2.43E-08	Pu-238 3.22E-09
Reg. 3	H-3 5.3E-07	H-3 1.20E-02	H-3 6.10E-04	Co-60 1.05E-07	Co-60 9.90E-10	H-3 8.52E-04	U-238 7.74E-09	Pu-238 1.76E-07	H-3 5.2E-09	U-238 6.56E-04	H-3 2.34E-06	H-3 3.15E-05	U-238 7.48E-07	Pu-238 4.09E-05	Pu-238 7.30E-09	H-3 1.68E-03	H-3 1.06E-07	U-238 1.33E-07	U-238 2.43E-08	Pu-238 3.22E-09
Reg. 4	H-3 5.3E-07	H-3 1.20E-02	H-3 6.51E-04	Co-60 1.05E-07	Co-60 9.90E-10	H-3 3.79E-05	U-238 7.74E-09	Pu-238 1.76E-07	H-3 5.2E-09	U-238 8.04E-04	H-3 2.34E-06	U-238 1.65E-08	U-238 7.48E-07	Pu-238 8.15E-07	Pu-238 7.30E-09	H-3 1.68E-03	H-3 1.06E-07	U-238 1.33E-07	U-238 2.43E-08	Pu-238 3.24E-09
Cen.	H-3 5.3E-07	H-3 2.30E-02	H-3 4.83E-06	Co-60 1.05E-07	Co-60 9.90E-10	H-3 3.79E-05	U-238 7.74E-09	Pu-238 1.76E-07	H-3 5.2E-09	U-238 2.18E-06	H-3 2.34E-06	U-238 1.65E-08	U-238 7.48E-07	Pu-238 8.15E-07	Pu-238 7.30E-09	H-3 9.81E-07	H-3 1.06E-07	U-238 1.33E-07	U-238 2.43E-08	Pu-238 3.24E-09
RH	H-3 5.3E-07	Pu-238 3.08E-07	H-3 1.95E-04							H-3 7.66E-04						H-3 2.80E-05				

Notes: Alt. = Alternative; Dec. = Decentralized; Reg. = Regionalized; Cen. = Centralized; RH = remote-handled low-level mixed waste.
[a] Radionuclide contributing most risk.
[b] Associated risk of cancer fatality to the offsite population within 80 km (50 mi) of this site.

Table D.3.5-7. Programwide Risks Associated With Treatment of LLMW Under the No Action Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	2.5E+01			
	Cancer fatalities	1.3E-02			
	Cancer incidence	4.3E-02	5.7E-04		
	Genetic effects	2.5E-03			
Noninvolved worker MEI	Dose (rem)	1.7E-02			
	Cancer fatalities	8.7E-06			
	Cancer incidence	3.0E-05	2.1E-07		
	Genetic effects	1.7E-06			
	Hazard index			4.5E-05	
Offsite population	Dose (person-rem)	5.7E+02			
	Cancer fatalities	2.8E-01			
	Cancer incidence	1.0	2.5E-03		
	Genetic effects	5.7E-02			
Offsite MEI	Dose (rem)	7.0E-03			
	Cancer fatalities	3.5E-06			
	Cancer incidence	1.2E-05	2.0E-08		
	Genetic effects	7.0E-07			
	Hazard index			2.3E-05	
WM workers	Dose (FTE-rem)	2.1E+03			
	Cancer fatalities	8.4E-01			
	Cancer incidence	2.9	1.1E-02		
	Genetic effects	1.3E-01			
	Exposure index			1.2E-02	
	Construction fatalities				6.0E-01
	Construction injuries				2.6E+02
	Operation fatalities				1.1
	Operation injuries				9.2E+02

Table D.3.5-8. Programwide Risks Associated With Treatment of LLMW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	4.7			
	Cancer fatalities	2.4E-03			
	Cancer incidence	8.0E-03	1.4E-05		
	Genetic effects	4.7E-04			
Noninvolved worker MEI	Dose (rem)	1.5E-03			
	Cancer fatalities	7.3E-07			
	Cancer incidence	2.5E-06	7.1E-09		
	Genetic effects	1.5E-07			
	Hazard index			8.8E-06	
Offsite population	Dose (person-rem)	3.4E+02			
	Cancer fatalities	1.7E-01			
	Cancer incidence	5.8E-01	4.4E-05		
	Genetic effects	3.4E-02			
Offsite MEI	Dose (rem)	5.0E-03			
	Cancer fatalities	2.5E-06			
	Cancer incidence	8.5E-06	1.2E-09		
	Genetic effects	5.0E-07			
	Hazard index			1.4E-06	
WM workers	Dose (FTE-rem)	1.3E+03			
	Cancer fatalities	5.2E-01			
	Cancer incidence	1.8	9.7E-03		
	Genetic effects	7.7E-02			
	Exposure index			1.2E-02	
	Construction fatalities				2.2
	Construction injuries				9.2E+02
	Operation fatalities				1.8
	Operation injuries				1.5E+03

Table D.3.5–9. Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	4.7			
	Cancer fatalities	2.4E–03			
	Cancer incidence	8.0E–03	1.3E–05		
	Genetic effects	4.7E–04			
Noninvolved worker MEI	Dose (rem)	1.5E–03			
	Cancer fatalities	7.4E–07			
	Cancer incidence	2.5E–06	6.2E–09		
	Genetic effects	1.5E–07			
	Hazard index			8.7E–06	
Offsite population	Dose (person-rem)	3.3E+02			
	Cancer fatalities	1.6E–01			
	Cancer incidence	5.5E–01	4.6E–05		
	Genetic effects	3.3E–02			
Offsite MEI	Dose (rem)	5.1E–03			
	Cancer fatalities	2.6E–06			
	Cancer incidence	8.7E–06	1.0E–09		
	Genetic effects	5.1E–07			
	Hazard index			1.4E–06	
WM workers	Dose (FTE-rem)	1.4E+03			
	Cancer fatalities	5.6E–01			
	Cancer incidence	2.0	9.2E–03		
	Genetic effects	8.4E–02			
	Exposure index			1.2E–02	
	Construction fatalities				2.0
	Construction injuries				8.6E+02
	Operation fatalities				1.7
	Operation injuries				1.5E+03

Table D.3.5-10. Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	7.2E-01			
	Cancer fatalities	3.6E-04			
	Cancer incidence	1.2E-03	1.5E-05		
	Genetic effects	7.2E-05			
Noninvolved worker MEI	Dose (rem)	6.1E-04			
	Cancer fatalities	3.1E-07			
	Cancer incidence	1.0E-06	6.2E-09		
	Genetic effects	6.1E-08			
	Hazard index			8.8E-06	
Offsite population	Dose (person-rem)	3.6E+01			
	Cancer fatalities	1.8E-02			
	Cancer incidence	6.1E-02	3.8E-05		
	Genetic effects	3.6E-03			
Offsite MEI	Dose (rem)	5.4E-04			
	Cancer fatalities	2.7E-07			
	Cancer incidence	9.2E-07	1.0E-09		
	Genetic effects	5.4E-08			
	Hazard index			1.4E-06	
WM workers	Dose (FTE-rem)	1.4E+03			
	Cancer fatalities	5.7E-01			
	Cancer incidence	2.0	9.6E-03		
	Genetic effects	8.5E-02			
	Exposure index			1.3E-02	
	Construction fatalities				1.8
	Construction injuries				7.7E+02
	Operation fatalities				1.6
	Operation injuries				1.4E+03

Table D.3.5-11. Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	7.2E-01			
	Cancer fatalities	3.6E-04			
	Cancer incidence	1.2E-03	1.1E-05		
	Genetic effects	9.2E-05			
Noninvolved worker MEI	Dose (rem)	6.1E-04			
	Cancer fatalities	3.1E-07			
	Cancer incidence	1.0E-06	6.2E-09		
	Genetic effects	6.1E-08			
	Hazard index			8.8E-06	
Offsite population	Dose (person-rem)	3.6E+01			
	Cancer fatalities	1.8E-02			
	Cancer incidence	6.1E-02	3.2E-05		
	Genetic effects	3.6E-03			
Offsite MEI	Dose (rem)	5.4E-04			
	Cancer fatalities	2.7E-07			
	Cancer incidence	9.2E-07	1.0E-09		
	Genetic effects	5.4E-08			
	Hazard index			1.4E-06	
WM workers	Dose (FTE-rem)	1.4E+03			
	Cancer fatalities	5.7E-01			
	Cancer incidence	2.0	9.6E-03		
	Genetic effects	8.5E-02			
	Exposure index			1.3E-02	
	Construction fatalities				1.8
	Construction injuries				7.7E+02
	Operation fatalities				1.6
	Operation injuries				1.4E+03

Table D.3.5-12. Programwide Risks Associated With Treatment of LLMW Under Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	7.1E-01			
	Cancer fatalities	3.6E-04			
	Cancer incidence	1.2E-03	1.3E-05		
	Genetic effects	7.1E-05			
Noninvolved worker MEI	Dose (rem)	6.3E-04			
	Cancer fatalities	3.1E-07			
	Cancer incidence	1.1E-06	9.3E-09		
	Genetic effects	6.3E-08			
	Hazard index			1.3E-05	
Offsite population	Dose (person-rem)	3.5E+01			
	Cancer fatalities	1.8E-02			
	Cancer incidence	5.9E-02	3.4E-05		
	Genetic effects	3.5E-03			
Offsite MEI	Dose (rem)	5.5E-04			
	Cancer fatalities	2.7E-07			
	Cancer incidence	9.3E-07	1.5E-09		
	Genetic effects	5.5E-08			
	Hazard index			2.0E-06	
WM workers	Dose (FTE-rem)	1.6E+03			
	Cancer fatalities	6.2E-01			
	Cancer incidence	2.2	1.2E-02		
	Genetic effects	9.4E-02			
	Exposure index			1.6E-02	
	Construction fatalities				1.6
	Construction injuries				6.9E+02
	Operation fatalities				1.5
	Operation injuries				1.3E+03

Table D.3.5–13. Programwide Risks Associated With Treatment of LLMW Under the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	6.6E–01			
	Cancer fatalities	3.3E–04			
	Cancer incidence	1.1E–03	7.9E–06		
	Genetic effects	6.6E–05			
Noninvolved worker MEI	Dose (rem)	1.2E–03			
	Cancer fatalities	5.8E–07			
	Cancer incidence	2.0E–06	1.4E–08		
	Genetic effects	1.2E–07			
	Hazard index			1.6E–05	
Offsite population	Dose (person-rem)	5.0E+01			
	Cancer fatalities	2.5E–02			
	Cancer incidence	8.6E–02	1.5E–05		
	Genetic effects	5.0E–03			
Offsite MEI	Dose (rem)	1.0E–03			
	Cancer fatalities	5.2E–07			
	Cancer incidence	1.8E–06	4.1E–10		
	Genetic effects	1.0E–07			
	Hazard index			4.5E–07	
WM workers	Dose (FTE-rem)	1.6E+03			
	Cancer fatalities	6.3E–01			
	Cancer incidence	2.2	1.8E–02		
	Genetic effects	9.5E–02			
	Exposure index			2.6E–02	
	Construction fatalities				1.4
	Construction injuries				6.0E+02
	Operation fatalities				1.2
	Operation injuries				9.8E+02

Table D.3.5-14. Programwide Risks Associated With Treatment of RH-LLMW Under Each Alternative Except No Action, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Noninvolved worker population	Dose (person-rem)	8.4E-02			
	Cancer fatalities	4.2E-05			
	Cancer incidence	1.4E-04	3.9E-08		
	Genetic effects	8.4E-06			
Noninvolved worker MEI	Dose (rem)	4.6E-05			
	Cancer fatalities	2.3E-08			
	Cancer incidence	7.8E-08	1.8E-11		
	Genetic effects	4.6E-09			
	Hazard index			3.8E-08	
Offsite population	Dose (person-rem)	2.7			
	Cancer fatalities	1.3E-03			
	Cancer incidence	4.5E-03	7.2E-08		
	Genetic effects	2.7E-04			
Offsite MEI	Dose (rem)	6.8E-05			
	Cancer fatalities	3.4E-08			
	Cancer incidence	1.2E-07	2.9E-12		
	Genetic effects	6.8E-09			
	Hazard index			4.8E-09	
WM workers	Dose (FTE-rem)	5.8E+01			
	Cancer fatalities	2.3E-02			
	Cancer incidence	8.1E-02	6.7E-05		
	Genetic effects	3.5E-03			
	Exposure index			4.6E-04	
	Construction fatalities				2.9E-01
	Construction injuries				1.3E+02
	Operation fatalities				1.6E-01
	Operation injuries				1.4E+02

Table D.3.5-15. Risks Associated With Treatment of LLMW Under the No Action Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
FEMP	2,764,589 165	3.2E-04	6.0E-09	1.4E-02	1.1E-03	2.1E-08	1.3E-03
KAPL-K	1,290,172 13	5.8E-04	1.3E-08	2.0E-03	2.0E-03	4.4E-08	3.2E-03
LBL	1,586,829 11	2.2E-05	3.3E-10	9.7E-04	7.7E-05	1.2E-09	9.2E-05
LANL	159,152 136	7.5E-05	8.0E-09	1.2E-02	2.6E-04	2.8E-08	2.9E-03
LLNL	6,324,234 220	9.5E-04	1.6E-08	1.9E-02	3.3E-03	5.5E-08	2.9E-03
Mound	3,032,983 7	1.3E-05	7.3E-10	5.8E-04	4.4E-05	2.5E-09	5.3E-05
NTS	14,266 330	5.8E-06	1.5E-09	3.9E-02	2.0E-05	5.1E-09	4.2E-02
Pantex	265,185 46	1.1E-06	9.2E-11	4.0E-03	3.8E-06	3.2E-10	6.1E-04
Ports	639,602 435	3.2E-05	4.0E-09	3.4E-02	1.7E-04	2.3E-08	4.5E-03
SNL-NM	610,714 8	3.8E-05	1.5E-09	6.6E-04	1.3E-04	5.2E-09	8.4E-05
Hanford	377,645 506	7.6E-03	1.6E-07	1.4E-01	2.6E-02	5.3E-07	3.7E-01
RFETS	2,171,877 2,407	1.3E-02	1.8E-07	2.4E-01	4.6E-02	6.1E-07	6.3E-03
WVDP	1,698,391 9	1.4E-04	2.1E-09	7.9E-04	4.7E-04	7.0E-09	1.1E-04
KCP	1,729,833 0	5.5E-06	2.5E-10	3.2E-05	1.9E-05	8.5E-10	3.8E-06
SRS	620,618 1,005	1.6E-03	1.5E-08	2.1E-01	5.3E-03	5.0E-08	4.8E-01
ORR	881,652 2,434	1.1E-01	3.5E-06	3.6E-01	3.9E-01	1.2E-05	7.0E-01
PGDP	500,502 55	1.8E-03	2.0E-07	4.8E-03	6.1E-03	6.8E-07	6.1E-04
INEL	153,061 782	5.6E-04	7.0E-08	1.8E-01	1.9E-03	2.4E-07	4.2E-01
BNL	5,738,554 24	1.1E-04	1.5E-09	2.1E-03	4.0E-04	5.3E-09	2.6E-04
ANL-E	7,939,785 22	2.6E-04	1.4E-09	1.9E-03	8.9E-04	4.9E-09	2.3E-04
Total		2.8E-01	3.5E-06	2.5E+0	1.0	1.2E-05	2.9

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5–16. Risks Associated With Treatment of LLMW Under the Decentralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
BNL	5,738,554 62	1.2E-05	1.6E-10	1.6E-02	4.1E-05	5.5E-10	4.3E-04
FEMP	2,764,589 533	2.6E-05	4.9E-10	1.6E-01	9.1E-05	1.7E-09	1.1E-03
KAPL-K	1,290,172 44	3.0E-04	6.7E-09	1.3E-02	1.0E-03	2.3E-08	6.2E-03
LBL	5,856,829 40	1.0E-02	1.6E-07	1.0E-02	3.5E-02	5.5E-07	1.3E-04
LANL	159,152 590	5.9E-04	6.2E-08	2.0E-01	2.0E-03	2.1E-07	5.5E-03
LLNL	6,324,234 831	1.5E-01	2.5E-06	2.7E-01	5.2E-01	8.5E-06	2.8E-02
ORR	881,652 2,530	1.1E-03	3.3E-08	7.7E-01	3.7E-03	1.2E-07	6.2E-01
Mound	3,032,983 7	1.3E-04	7.4E-09	2.1E-03	4.3E-04	2.5E-08	4.7E-05
NTS	14,266 785	7.9E-07	2.0E-10	1.1E-01	2.7E-06	6.9E-10	4.8E-02
Pantex	265,185 145	3.5E-05	2.9E-09	3.9E-02	1.2E-04	1.0E-08	1.2E-03
PORTS	639,602 1,853	2.7E-06	3.4E-10	4.8E-01	1.2E-05	1.5E-09	5.6E-03
SNL-NM	610,714 20	1.4E-04	5.4E-09	5.4E-03	4.7E-04	1.9E-08	1.2E-03
SRS	620,618 1,289	1.7E-03	1.7E-08	4.3E-01	5.9E-03	5.6E-08	3.7E-01
RFETS	2,171,877 2305	6.7E-05	9.1E-10	6.3E-01	2.3E-04	3.1E-09	4.1E-03
WVDP	1,698,391 11	2.5E-07	3.8E-12	6.8E-03	8.6E-07	1.3E-11	8.6E-03
KCP	1,729,833 1	3.9E-06	1.8E-10	2.6E-04	1.3E-05	6.0E-10	1.2E-04
INEL	153,061 1,588	5.2E-05	6.5E-09	5.3E-01	1.8E-04	2.2E-08	3.6E-01
Hanford	377,645 2,196	1.5E-03	3.0E-08	6.2E-01	5.0E-03	1.0E-07	3.6E-01
PGDP	500,502 144	1.2E-04	1.3E-08	4.7E-02	4.1E-04	4.5E-08	8.4E-04
ANL-E	7,939,785 50	1.7E-05	9.1E-11	6.4E-03	5.6E-05	3.1E-10	2.3E-04
Total		1.7E-01	2.5E-06	4.5	5.8E-01	8.5E-06	1.8

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-17. Risks Associated With Treatment of LLMW Under the Regionalized Alternative 1, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
BNL	5,738,554 16	5.2E-08	7.0E-13	4.0E-03	1.9E-07	2.5E-12	2.0E-04
FEMP	2,764,589 1,233	7.0E-04	1.3E-08	3.5E-01	2.4E-03	4.5E-08	9.5E-02
KAPL-K	1,290,172 9	2.6E-07	5.8E-12	2.8E-03	8.9E-07	2.0E-11	2.2E-03
LBL	5,856,829 8	9.8E-09	1.5E-13	1.9E-03	4.9E-08	8.3E-13	7.4E-05
LANL	159,152 597	6.1E-04	6.4E-08	2.0E-01	2.1E-03	2.2E-07	6.4E-03
LLNL	6,324,234 915	1.6E-01	2.6E-06	3.1E-01	5.3E-01	8.7E-06	8.1E-02
ORR	881,652 2,162	9.3E-04	2.9E-08	5.9E-01	3.2E-03	9.8E-08	3.9E-01
Mound	3,032,983 5	5.9E-09	3.4E-13	1.1E-03	7.3E-08	2.9E-12	4.3E-05
NTS	14,266 305	6.4E-09	1.6E-12	4.9E-02	2.2E-08	5.4E-12	1.0E-02
Pantex	265,185 145	3.5E-05	2.9E-09	3.9E-02	1.2E-04	1.0E-08	1.2E-03
PORTS	639,602 1,353	4.9E-05	6.0E-09	4.0E-01	1.7E-04	2.1E-08	2.1E-01
SNL-NM	610,714 5	1.8E-08	7.1E-13	1.2E-03	6.1E-08	2.4E-12	6.1E-05
SRS	620,618 1,290	1.8E-03	1.7E-08	4.4E-01	6.0E-03	5.7E-08	3.8E-01
RFETS	2,171,877 2,307	6.7E-05	9.0E-10	6.3E-01	2.3E-04	3.1E-09	4.1E-03
WVDP	1,698,391 10	1.7E-07	2.6E-12	3.2E-03	5.9E-07	8.9E-12	9.7E-05
KCP	1,729,833 0	2.5E-09	1.1E-13	5.9E-05	8.4E-09	3.8E-13	2.8E-06
Hanford	377,645 2,065	1.4E-03	2.8E-08	6.0E-01	4.7E-03	9.6E-08	4.2E-01
INEL	153,061 1,587	5.2E-05	6.5E-09	5.3E-01	1.8E-04	2.2E-08	3.6E-01
PGDP	500,502 144	1.2E-04	1.3E-08	4.7E-02	4.1E-04	4.5E-08	1.4E-03
ANL-E	7,939,785 23	5.9E-07	3.3E-12	3.8E-03	2.0E-06	1.1E-11	1.1E-04
Total		1.6E-01	2.6E-06	4.3	5.5E-01	8.7E-06	2.0

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-18. Risks Associated With Treatment of LLMW Under Regionalized Alternative 2, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 23	5.9E-07	3.3E-12	3.8E-03	2.0E-06	1.1E-11	1.1E-04
BNL	5,738,554 16	5.2E-08	7.0E-13	4.0E-03	1.9E-07	2.5E-12	2.0E-04
FEMP	2,764,589 269	1.4E-07	2.7E-12	8.8E-02	5.8E-07	1.2E-11	8.8E-04
KAPL-K	1,290,172 9	2.6E-07	5.8E-12	2.8E-03	8.9E-07	2.0E-11	2.2E-03
LBL	5,856,829 8	9.8E-09	1.5E-13	1.9E-03	4.9E-08	8.3E-13	7.4E-05
LANL	159,152 679	8.6E-04	9.1E-08	2.2E-01	2.9E-03	3.1E-07	8.2E-03
LLNL	6,324,234 136	4.4E-07	7.2E-12	3.3E-02	1.9E-06	3.5E-11	2.2E-03
ORR	881,652 2,177	1.2E-03	3.6E-08	6.0E-01	4.1E-03	1.3E-07	4.2E-01
Mound	3,032,983 5	5.9E-09	3.4E-13	1.1E-03	7.3E-08	2.9E-12	4.3E-05
NTS	14,266 305	6.4E-09	1.6E-12	4.9E-02	2.2E-08	5.4E-12	1.0E-02
Pantex	265,185 48	2.3E-06	2.0E-10	1.5E-02	8.0E-06	6.8E-10	5.8E-04
PORTS	639,602 1,951	1.1E-04	1.3E-08	5.4E-01	3.6E-04	4.5E-08	2.7E-01
SNL-NM	610,714 5	1.8E-08	7.1E-13	1.2E-03	6.1E-08	2.4E-12	6.1E-05
SRS	620,618 1,290	1.8E-03	1.7E-08	4.4E-01	6.0E-03	5.7E-08	3.8E-01
RFETS	2,171,877 2,307	6.8E-05	9.2E-10	6.3E-01	2.4E-04	3.2E-09	4.6E-03
WVDP	1,698,391 10	1.7E-07	2.6E-12	3.2E-03	5.8E-07	8.9E-12	9.7E-05
KCP	1,729,833 0	2.5E-09	1.1E-13	5.9E-05	8.4E-09	3.8E-13	2.8E-06
INEL	153,061 2,010	6.3E-04	7.8E-08	6.6E-01	2.1E-03	2.7E-07	3.9E-01
Hanford	377,645 2,132	1.3E-02	2.7E-07	6.4E-01	4.5E-02	9.2E-07	5.0E-01
PGDP	500,502 48	8.1E-07	9.0E-11	1.3E-02	2.8E-06	3.1E-10	5.2E-04
Total		1.8E-02	2.7E-07	4.0	6.1E-02	9.2E-07	2.0

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-19. Risks Associated With Treatment of LLMW Under Regionalized Alternative 3, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 23	5.9E-07	3.3E-12	3.8E-03	2.0E-06	1.1E-11	1.1E-04
BNL	5,738,554 16	5.2E-08	7.0E-13	4.0E-03	1.9E-07	2.5E-12	2.0E-04
FEMP	2,764,589 269	1.4E-07	2.7E-12	8.8E-02	5.8E-07	1.2E-11	8.8E-04
KAPL-K	1,290,172 9	2.6E-07	5.8E-12	2.8E-03	8.9E-07	2.0E-11	2.2E-03
LBL	5,856,829 8	9.8E-09	1.5E-13	1.9E-03	4.9E-08	8.3E-13	7.4E-05
LANL	159,152 679	8.6E-04	9.1E-08	2.2E-01	2.9E-03	3.1E-07	8.2E-03
LLNL	6,324,234 136	4.4E-07	7.2E-12	3.3E-02	1.9E-06	3.5E-11	2.2E-03
ORR	881,652 2,177	1.2E-03	3.6E-08	6.0E-01	4.1E-03	1.3E-07	4.2E-01
Mound	3,032,983 5	5.9E-09	3.4E-13	1.1E-03	7.3E-08	2.9E-12	4.3E-05
NTS	14,266 305	6.4E-09	1.6E-12	4.9E-02	2.2E-08	5.4E-12	1.0E-02
Pantex	265,185 48	2.3E-06	2.0E-10	1.5E-02	8.0E-06	6.8E-10	5.8E-04
PORTS	639,602 1,951	1.1E-04	1.3E-08	5.4E-01	3.6E-04	4.5E-08	2.7E-01
SNL-NM	610,714 5	1.8E-08	7.1E-13	1.2E-03	6.1E-08	2.4E-12	6.1E-05
SRS	620,618 1,290	1.8E-03	1.7E-08	4.4E-01	6.0E-03	5.7E-08	3.8E-01
RFETS	2,171,877 2,307	6.8E-05	9.2E-10	6.3E-01	2.4E-04	3.2E-09	4.6E-03
WVDP	1,698,391 10	1.7E-07	2.6E-12	3.2E-03	5.8E-07	8.9E-12	9.7E-05
KCP	1,729,833 0	2.5E-09	1.1E-13	5.9E-05	8.4E-09	3.8E-13	2.8E-06
Hanford	377,645 2,132	1.3E-02	2.7E-07	6.4E-01	4.5E-02	9.2E-07	5.0E-01
INEL	153,061 2,010	6.3E-04	7.8E-08	6.6E-01	2.1E-03	2.7E-07	3.9E-01
PGDP	500,502 48	8.1E-07	9.0E-11	1.3E-02	2.8E-06	3.1E-10	5.2E-04
Total		1.8E-02	2.7E-07	4.0	6.1E-02	9.2E-07	2.0

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-20. Risks Associated With Treatment of LLMW Under Regionalized Alternative 4, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 23	5.9E-07	3.3E-12	3.8E-03	2.0E-06	1.1E-11	1.1E-04
BNL	5,738,554 16	5.2E-08	7.0E-13	4.0E-03	1.9E-07	2.5E-12	2.0E-04
FEMP	2,764,589 269	1.4E-07	2.7E-12	8.8E-02	5.8E-07	1.2E-11	8.8E-04
KAPL-K	1,290,172 9	2.6E-07	5.8E-12	2.8E-03	8.9E-07	2.0E-11	2.2E-03
LBL	5,856,829 8	9.8E-09	1.5E-13	1.9E-03	4.9E-08	8.3E-13	7.4E-05
LANL	159,152 146	3.8E-05	4.0E-09	4.4E-02	1.3E-04	1.4E-08	2.4E-03
LLNL	6,324,234 136	4.4E-07	7.2E-12	3.3E-02	1.9E-06	3.5E-11	2.2E-03
ORR	881,652 3,116	1.6E-03	5.0E-08	9.5E-01	5.6E-03	1.7E-07	8.5E-01
Mound	3,032,983 5	6.0E-09	3.5E-13	1.2E-03	7.4E-08	2.9E-12	4.6E-05
NTS	14,266 305	6.4E-09	1.6E-12	4.9E-02	2.2E-08	5.4E-12	1.0E-02
Pantex	265,185 48	2.3E-06	2.0E-10	1.5E-02	8.0E-06	6.8E-10	5.8E-04
PORTS	639,602 405	1.8E-08	2.3E-12	1.2E-01	1.1E-07	1.6E-11	2.9E-03
SNL-NM	610,714 5	1.8E-08	7.1E-13	1.2E-03	6.1E-08	2.4E-12	6.1E-05
SRS	620,618 1,291	1.8E-03	1.7E-08	4.4E-01	6.0E-03	5.7E-08	3.8E-01
RFETS	2,171,877 769	1.3E-06	1.8E-11	2.1E-01	4.9E-06	6.4E-11	3.5E-03
WVDP	1,698,391 11	1.7E-07	2.6E-12	3.3E-03	6.0E-07	9.1E-12	1.0E-04
KCP	1,729,833 0	2.5E-09	1.1E-13	5.9E-05	8.4E-09	3.8E-13	2.8E-06
INEL	153,061 3,281	6.7E-04	8.4E-08	1.0	2.3E-03	2.8E-07	4.2E-01
Hanford	377,645 2,268	1.3E-02	2.7E-07	6.9E-01	4.5E-02	9.3E-07	5.2E-01
PGDP	500,502 48	8.1E-07	9.0E-11	1.3E-02	2.8E-06	3.1E-10	5.2E-04
Total		1.8E-02	2.7E-07	3.7	5.9E-02	9.3E-07	2.2

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-21. Risks Associated With Treatment of LLMW Under the Centralized Alternative, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
ANL-E	7,939,785 23	5.9E-07	3.3E-12	3.8E-03	2.0E-06	1.1E-11	1.1E-04
BNL	5,738,554 16	5.2E-08	7.0E-13	4.0E-03	1.9E-07	2.5E-12	2.0E-04
FEMP	2,764,589 269	1.4E-07	2.7E-12	8.8E-02	5.8E-07	1.2E-11	8.8E-04
KAPL-K	1,290,172 9	2.6E-07	5.8E-12	2.8E-03	8.9E-07	2.0E-11	2.2E-03
LBL	5,856,829 8	9.8E-09	1.5E-13	1.9E-03	4.9E-08	8.3E-13	7.4E-05
LANL	159,152 146	3.8E-05	4.0E-09	4.4E-02	1.3E-04	1.4E-08	2.4E-03
LLNL	6,324,234 136	4.4E-07	7.2E-12	3.3E-02	1.9E-06	3.5E-11	2.2E-03
ORR	881,652 490	6.8E-06	2.1E-10	1.6E-01	2.4E-05	7.7E-10	8.4E-02
Mound	3,032,983 5	6.0E-09	3.5E-13	1.2E-03	7.4E-08	2.9E-12	4.6E-05
NTS	14,266 305	6.4E-09	1.6E-12	4.9E-02	2.2E-08	5.4E-12	1.0E-02
Pantex	265,185 48	2.3E-06	2.0E-10	1.5E-02	8.0E-06	6.8E-10	5.8E-04
PORTS	639,602 405	1.8E-08	2.3E-12	1.2E-01	1.1E-07	1.6E-11	2.9E-03
SNL-NM	610,714 5	1.8E-08	7.1E-13	1.2E-03	6.1E-08	2.4E-12	6.1E-05
SRS	620,618 207	1.3E-06	1.3E-11	8.1E-02	4.6E-06	4.4E-11	1.1E-01
RFETS	2,171,877 769	1.3E-06	1.8E-11	2.1E-01	4.9E-06	6.4E-11	3.5E-03
WVDP	1,698,391 11	1.7E-07	2.6E-12	3.3E-03	5.9E-07	9.1E-12	1.0E-04
KCP	1,729,833 0	2.5E-09	1.1E-13	5.9E-05	8.4E-09	3.8E-13	2.8E-06
INEL	153,061 278	4.9E-06	6.1E-10	1.5E-01	1.7E-05	2.1E-09	2.5E-01
Hanford	377,645 6,706	2.5E-02	5.2E-07	2.2	8.5E-02	1.8E-06	1.8
PGDP	500,502 48	8.1E-07	9.0E-11	1.3E-02	2.8E-06	3.1E-10	5.2E-04
Total		2.5E-02	5.2E-07	3.2	8.6E-02	1.8E-06	2.3

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5–22. Risks Associated With Treatment of RH-LLMW Under Each Alternative Except No Action, by Site

Site	Population[a]	Fatalities[b]			Cancer Incidence[c]		
		Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Hanford	377,645 1	4.4E-07	9.1E-12	1.7E-04	1.5E-06	3.1E-11	2.4E-09
ORR	881,652 725	1.1E-03	3.4E-08	3.0E-01	3.7E-03	1.2E-07	7.5E-02
INEL	153,061 569	2.1E-04	2.6E-08	1.7E-01	7.0E-04	8.7E-08	6.9E-03
SRS	620,618 17	3.0E-05	2.8E-10	5.1E-03	1.0E-04	9.6E-10	4.8E-06
Total		1.3E-03	3.4E-08	4.7E-01	4.5E-03	1.2E-07	8.1E-02

[a] Top number represents the offsite population within an 80-km radius of the site, while the bottom number represents the total FTEs for WM workers involved in both construction and operation activities.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5–23. Programwide Risks Associated With Disposal of LLMW Under the Decentralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	2.9			
	Cancer fatalities	1.5E-03			
	Cancer incidence	4.9E-03	9.8E-03		
	Genetic effects	2.9E-04			
	Hazard index			2.4	
All lifetimes	Dose (person-rem)	7.0E+01			
	Cancer fatalities	3.5E-02			
	Cancer incidence	1.2E-01	4.9E-01		
	Genetic effects	7.0E-03			
	Hazard index			2.4	
WM workers	Dose (FTE-rem)	1.4E+03			
	Cancer fatalities	5.5E-01			
	Cancer incidence	1.9			
	Genetic effects	8.3E-02			
	Exposure index				
	Construction fatalities				1.1E-01
	Construction injuries				5.1E+01
	Operation fatalities				3.2E-01
	Operation injuries				2.7E+02

Table D.3.5-24. Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 1, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	2.4			
	Cancer fatalities	1.2E-03			
	Cancer incidence	4.1E-03	9.8E-03		
	Genetic effects	2.4E-04			
	Hazard index			3.0	
All lifetimes	Dose (person-rem)	4.7E+01			
	Cancer fatalities	2.4E-02			
	Cancer incidence	8.0E-02	5.0E-01		
	Genetic effects	4.7E-03			
	Hazard index			3.0	
WM workers	Dose (FTE-rem)	1.4E+03			
	Cancer fatalities	5.5E-01			
	Cancer incidence	1.9			
	Genetic effects	8.3E-02			
	Exposure index				
	Construction fatalities				1.2E-01
	Construction injuries				5.5E+01
	Operation fatalities				3.4E-01
	Operation injuries				2.9E+02

Table D.3.5-25. Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 2, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	2.8			
	Cancer fatalities	1.4E-03			
	Cancer incidence	4.8E-03	1.3E-02		
	Genetic effects	2.8E-04			
	Hazard index			2.7	
All lifetimes	Dose (person-rem)	4.7E+01			
	Cancer fatalities	2.4E-02			
	Cancer incidence	8.0E-02	8.3E-01		
	Genetic effects	4.7E-03			
	Hazard index			2.7	
WM workers	Dose (FTE-rem)	1.3E+03			
	Cancer fatalities	5.2E-01			
	Cancer incidence	1.8			
	Genetic effects	7.8E-02			
	Exposure index				
	Construction fatalities				1.1E-01
	Construction injuries				4.7E+01
	Operation fatalities				3.1E-01
	Operation injuries				2.6E+02

Table D.3.5-26. Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 3, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	0.00			
	Cancer fatalities	0.00			
	Cancer incidence	0.00	7.2E-04		
	Genetic effects	0.00			
	Hazard index			8.1E-01	
All lifetimes	Dose (person-rem)	0.00			
	Cancer fatalities	0.00			
	Cancer incidence	0.00	3.0E-02		
	Genetic effects	0.00			
	Hazard index			8.1E-01	
WM workers	Dose (FTE-rem)	9.8E+02			
	Cancer fatalities	3.9E-01			
	Cancer incidence	1.4			
	Genetic effects	5.9E-02			
	Exposure index				
	Construction fatalities				9.5E-03
	Construction injuries				2.6
	Operation fatalities				7.5E-02
	Operation injuries				2.0E+01

Table D.3.5-27. Programwide Risks Associated With Disposal of LLMW Under Regionalized Alternative 4, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	3.0			
	Cancer fatalities	1.5E-03			
	Cancer incidence	5.1E-03	1.3E-02		
	Genetic effects	3.0E-04			
	Hazard index			2.7	
All lifetimes	Dose (person-rem)	5.0E+01			
	Cancer fatalities	2.5E-02			
	Cancer incidence	8.5E-02	8.2E-01		
	Genetic effects	5.0E-03			
	Hazard index			2.7	
WM workers	Dose (FTE-rem)	1.6E+03			
	Cancer fatalities	6.4E-01			
	Cancer incidence	2.2			
	Genetic effects	9.5E-02			
	Exposure index				
	Construction fatalities				1.0E-01
	Construction injuries				4.4E+01
	Operation fatalities				3.1E-01
	Operation injuries				2.7E+02

Table D.3.5-28. Programwide Risks Associated With Disposal of LLMW Under the Centralized Alternative, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	3.9E+01			
	Cancer fatalities	1.9E-02			
	Cancer incidence	6.6E-02	9.5E-04		
	Genetic effects	3.9E-03			
	Hazard index			2.4	
All lifetimes	Dose (person-rem)	5.0E+02			
	Cancer fatalities	2.5E-01			
	Cancer incidence	8.6E-01	8.5E-03		
	Genetic effects	5.0E-02			
	Hazard index			2.4	
WM workers	Dose (FTE-rem)	9.1E+02			
	Cancer fatalities	3.6E-01			
	Cancer incidence	1.3			
	Genetic effects	5.4E-02			
	Exposure index				
	Construction fatalities				1.9E-02
	Construction injuries				8.1
	Operation fatalities				1.3E-01
	Operation injuries				1.1E+02

Table D.3.5-29. Programwide Risks Associated With Disposal of RH-LLMW Under Each Alternative Except No Action, by Health Endpoint

Receptor	Endpoint	Radionuclides	Hazardous Chemicals		Physical Hazards
			Carcinogens	Noncarcinogens	
Maximally exposed farm family	Dose (person-rem)	1.7E-01			
	Cancer fatalities	8.5E-05			
	Cancer incidence	2.9E-04	1.4E-05		
	Genetic effects	1.7E-05			
	Hazard index			1.3E-02	
All lifetimes	Dose (person-rem)	2.7			
	Cancer fatalities	1.3E-03			
	Cancer incidence	4.5E-03	5.8E-04		
	Genetic effects	2.7E-04			
	Hazard index			1.3E-02	
WM workers	Dose (FTE-rem)	3.7			
	Cancer fatalities	1.5E-03			
	Cancer incidence	5.2E-03			
	Genetic effects	2.2E-04			
	Exposure index				
	Construction fatalities				9.4E-03
	Construction injuries				4.1
	Operation fatalities				2.1E-02
	Operation injuries				1.8E+01

Table D.3.5–30. Risks Associated With Disposal of LLMW Under the Decentralized Alternative, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	9.4E-04	1.8E-02	2.8E-01	3.7E-03	6.5E-02	7.1E-01
INEL (0)	0.00	0.00	1.9E-01	3.0E-05	4.1E-05	4.9E-01
LLNL (142)	1.3E-06	2.0E-05	6.3E-02	7.8E-06	2.6E-04	1.4E-01
LANL (0)	0.00	0.00	1.3E-02	3.1E-04	5.5E-03	5.5E-03
NTS (0)	0.00	0.00	2.7E-02	8.8E-06	4.3E-04	4.5E-02
ORR (22)	3.8E-06	5.9E-05	1.3E-01	6.4E-03	4.5E-01	2.8E-01
PGDP (146)	7.8E-06	6.6E-05	3.1E-03	2.8E-05	2.4E-04	4.8E-04
Pantex (96)	2.7E-06	8.6E-05	5.1E-03	1.4E-05	3.6E-04	1.1E-03
PORTS (145)	3.1E-05	1.1E-03	6.6E-02	5.4E-04	8.8E-03	1.3E-01
RFETS (38)	1.6E-06	3.1E-05	7.1E-02	1.1E-03	2.5E-02	8.2E-03
SNL-NM (92)	1.8E-04	9.3E-03	7.7E-04	6.2E-04	3.2E-02	1.2E-04
SRS (153)	9.7E-05	1.3E-03	1.4E-01	1.3E-03	7.2E-03	1.4E-01
ANL-E (64)	3.4E-06	1.5E-04	3.4E-04	1.7E-05	6.4E-04	9.2E-05
BNL (78)	4.2E-05	2.6E-03	1.6E-03	1.8E-04	9.0E-03	2.1E-04
FEMP (53)	1.5E-04	2.5E-03	9.3E-03	7.8E-06	2.6E-04	1.0E-03
Total	1.5E-03	3.5E-02	9.6E-01	1.5E-02	6.1E-01	1.9

[a] Number in parentheses indicates the most-exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-31. Risks Associated With Disposal of LLMW Under Regionalized Alternative 1, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
FEMP (53)	1.5E-04	2.5E-03	9.3E-03	5.7E-04	8.7E-03	1.0E-03
INEL (0)	0.00	0.00	1.9E-01	3.0E-05	4.1E-05	4.9E-01
LLNL (142)	1.3E-06	2.0E-05	6.3E-02	7.8E-06	2.6E-04	1.4E-01
LANL (0)	0.00	0.00	1.3E-02	3.1E-04	5.5E-03	6.7E-03
NTS (0)	0.00	0.00	2.5E-04	8.1E-06	1.3E-04	2.7E-05
ORR (22)	3.0E-06	4.7E-05	1.2E-01	6.4E-03	4.5E-01	2.5E-01
PGDP (146)	7.8E-06	6.6E-05	3.1E-03	2.8E-05	2.4E-04	4.8E-04
Pantex (96)	2.7E-06	8.6E-05	5.1E-03	1.4E-05	3.6E-04	1.1E-03
PORTS (145)	8.5E-05	3.1E-03	1.1E-01	8.5E-04	1.7E-02	2.0E-01
RFETS (38)	1.6E-06	3.1E-05	7.1E-02	1.1E-03	2.5E-02	8.2E-03
SRS (153)	9.7E-05	1.3E-03	1.4E-01	1.3E-03	7.2E-03	1.4E-01
Hanford (18)	8.6E-04	1.7E-02	2.7E-01	3.4E-03	6.1E-02	7.0E-01
Total	1.2E-03	2.4E-02	9.9E-01	1.4E-02	5.8E-01	1.9

[a] Number in parentheses indicates the maximally exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-32. Risks Associated With Disposal of LLMW Under Regionalized Alternative 2, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.3E-03	2.2E-02	2.9E-01	4.9E-03	8.0E-02	7.4E-01
INEL (0)	0.00	0.00	2.2E-01	3.0E-05	4.2E-05	5.8E-01
LANL (0)	0.00	0.00	1.4E-01	1.7E-04	3.2E-03	4.0E-02
NTS (0)	0.00	0.00	0.00	0.00	0.00	0.00
ORR (22)	3.6E-06	5.8E-05	1.5E-01	1.2E-02	8.1E-01	3.3E-01
SRS (153)	9.7E-05	1.3E-03	1.4E-01	1.3E-03	7.2E-03	1.4E-01
Total	1.4E-03	2.4E-02	9.4E-01	1.8E-02	9.1E-01	1.8

[a] Number in parentheses indicates the maximally exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-33. Risks Associated With Disposal of LLMW Under Regionalized Alternative 3, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
NTS (0)	0.00	0.00	4.8E-01	7.2E-04	3.0E-02	1.4
Total	0.00	0.00	4.8E-01	7.2E-04	3.0E-02	1.4

[a] Number in parentheses indicates the maximally exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-34. Risks Associated With Disposal of LLMW Under Regionalized Alternative 4, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	4.0E-01	1.7E-05	2.2E-05	1.0
LANL (0)	0.00	0.00	7.6E-02	4.7E-07	8.4E-06	5.5E-03
NTS (0)	0.00	0.00	0.00	0.00	0.00	0.00
ORR (22)	4.3E-06	7.0E-05	1.5E-01	1.2E-02	8.2E-01	3.3E-01
SRS (153)	9.7E-05	1.3E-03	1.4E-01	1.3E-03	7.2E-03	1.4E-01
Hanford (18)	1.4E-03	2.4E-02	2.9E-01	5.2E-03	8.5E-02	7.4E-01
Total	1.5E-03	2.5E-02	1.1	1.8E-02	9.1E-01	2.2

[a] Number in parentheses indicates the maximally exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-35. Risks Associated With Disposal of LLMW Under the Centralized Alternative, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
Hanford (18)	1.9E-02	2.5E-01	5.1E-01	6.7E-02	8.7E-01	1.3
Total	1.9E-02	2.5E-01	5.1E-01	6.7E-02	8.7E-01	1.3

[a] Number in parentheses indicates the maximally exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

Table D.3.5-36. Risks Associated With Disposal of RH-LLMW Under Each Alternative Except No Action, by Site

Site (Lifetime)[a]	Fatalities[b]			Cancer Incidence[c]		
	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers	Maximally Exposed Farm Family	All Farm Family Lifetimes	WM Workers
INEL (0)	0.00	0.00	2.1E-02	7.6E-07	1.2E-06	3.5E-03
Hanford (18)	2.4E-07	5.0E-06	2.5E-05	8.5E-07	1.7E-05	3.2E-11
ORR (22)	8.3E-05	1.3E-03	9.7E-03	2.9E-04	5.0E-03	1.8E-03
SRS (153)	2.1E-06	2.9E-05	1.2E-03	1.2E-05	1.1E-04	2.2E-06
Total	8.5E-05	1.3E-03	3.2E-02	3.0E-04	5.1E-03	5.2E-03

[a] Number in parentheses indicates the maximally exposed lifetime of the farm family for radionuclide exposure only.
[b] Includes worker fatalities associated with both radiation exposures and physical hazards.
[c] Indicates cancer incidence associated with both radiation and chemical carcinogen exposures.

D.3.5.4 Results of the LLMW Human Health Risk Analysis for Routine Operations

D.3.5.4.1 *Programwide Trends in Human Health Risks Associated With LLMW Management Alternatives*

For the offsite and noninvolved worker populations and their respective MEIs, the cancer fatality risks associated with CH-LLMW treatment under Regionalized Alternatives 2, 3, 4, and the Centralized Alternative are generally lower than for No Action, Decentralization, and Regionalized 1 Alternatives, due to reduction in the number of treatment installations and the transfer of wastes to installations where offsite populations are smaller and/or farther away from treatment facilities. However, for the off-site population and both MEIs, cancer fatality risks in the Centralized Alternative are slightly higher (less than a factor of 2) than those associated with the Regionalized 2, 3, and 4 Alternatives. In all alternatives, radiological risks to offsite and noninvolved worker receptors are higher than risks from chemical exposure.

Risks of cancer incidence from chemical exposure to offsite and noninvolved worker populations and offsite MEIs follows a similar trend, decreasing as fewer installations treat LLMW. However, for the noninvolved worker MEI, chemical-related cancer incidence risk increases slightly when all treatment is performed at only one installation. All hazard indices are all well below 1.0, indicating a low probability of adverse health effects due to noncarcinogenic, toxic chemicals.

For both involved and noninvolved workers, the No Action Alternative (which entails treatment of RH- and CH-LLMW) and all the other CH-LLMW treatment alternatives are very similar for all health risk endpoints. However, the cancer incidence risks due to potential chemical exposure are one to two orders of magnitude lower than the cancer incidence risks due to radionuclide exposure. All exposure indices are well below 1.0, indicating a low probability of adverse health effects due to noncarcinogenic, toxic chemicals.

For all receptors, cancer risks associated with RH-LLMW treatment (all alternatives except No Action) are greater at ORR and INEL than at other installations because these two installations treat substantially large waste loads.

Offsite Population. The No Action, Decentralized (49-installation treatment) and Regionalized 1 (11-installation treatment) Alternatives produce risks of cancer fatality to the offsite population approximately one order of magnitude higher than the Regionalized 2, 3, 4, and Centralized Alternatives (7-, 7-, 4- and 1-installation treatment, respectively). This is because CH-LLMW is being transferred for treatment from LLNL (which has a population of 6.3 million located relatively close to the facility) to Hanford (which has a population of 380,000 located farther from the facility). Total cancer fatality risks for No Action, Decentralized, and Regionalized 1 Alternatives are in the range of 1.6E–01 to 2.8E–01 over a total affected population of approximately 53.2 million, whereas the risks from Regionalized 2, 3, 4, and Centralized Alternatives range from 1.8E–02 to 2.5E–02 for the same affected population.

For the No Action Alternative and alternatives involving treatment of CH-LLMW, most of the estimated cancer fatality risk can be attributed to exposure to uranium-238 at ORR (No Action), tritium at LLNL (Decentralized and Regionalized 1), and tritium at Hanford (Regionalized 2, 3, 4, and Centralized). Reported by alternatives, installations posing the highest risks are the same. (As discussed in Chapter 6, the risks estimated in this section are based on the assumption that LLMW will be incinerated. The highest health risk to the offsite population is estimated to result from releases of tritium during incineration of wastes containing tritium. It should be noted that DOE is exploring alternative technologies for treating LLMW where incineration is determined to be unacceptable based on potential health risks.

Cancer incidence risk to offsite populations from exposure to carcinogenic chemicals follows the trends for radiological risks, generally decreasing from the No Action Alternative to the Centralized Alternative. The highest chemical-related cancer risk is from the No Action Alterative (2.5E–03). This is approximately one to two orders of magnitude higher than the other alternatives. The lowest estimated cancer incidence due to chemical exposure is from the Centralized Alternative (1.5E–05).

The treatment of RH-LLMW at four installations presents a programwide risk of cancer fatality to the offsite population of 1.3E–03 over a total affected population of approximately 2 million (in all alternatives except the No Action Alternative). The highest installation-specific cancer fatality risk is associated with RH-LLMW treatment from ORR, due to tritium emissions during management of a relatively large waste volume. The estimated programwide risk of cancer incidence from chemical exposure in the RH-LLMW treatment scenario is 7.2E–08.

Noninvolved Worker Population. The programwide health risks to noninvolved worker populations parallel the trends observed for the offsite populations. Cancer fatality risks in the No Action, Decentralized, and Regionalized 1 Alternatives are approximately one to two orders of magnitude higher than in the Regionalized 2, 3, 4, and Centralized Alternatives. The risk of cancer fatality to noninvolved worker populations for CH-LLMW ranges from 3.3E–04 (Centralized) to 1.3E–02 (No Action).

The No Action Alternative presents the highest risk of cancer fatality (1.3E–02) to the noninvolved worker populations and is approximately one order of magnitude higher than the next highest alternative. The Decentralized and Regionalized 1 Alternatives produce risks of cancer fatality (2.4E–03) to the noninvolved worker population, approximately one order of magnitude higher than the Regionalized 2, 3, 4, and Centralized Alternatives. This is explained by the fact that a larger population of noninvolved workers is located closer to LLNL than to Hanford (9,500 versus 160, respectively).

The risk of cancer incidence to noninvolved worker populations from exposure to carcinogenic chemicals in CH-LLMW follows the same general trend as for offsite populations and ranges from 7.9E–06 (Centralized) to 5.7E–04 (No Action).

The treatment of RH-LLMW at four installations (all alternatives except No Action) results in a risk to noninvolved worker populations from chemical exposure of 4.2E–05 for cancer fatality and 3.9E–08 for cancer incidence.

Maximally Exposed Noninvolved Worker Individuals and Maximally Exposed Offsite Population Individuals (MEIs). For CH-LLMW, the trends in cancer fatality risks to offsite MEIs are similar to those for the offsite and noninvolved worker populations in that Regionalized 2, 3, 4, and Centralized Alternatives generally presented lower risks than the No Action, Decentralized, and Regionalized 1 Alternatives. Risk of cancer incidence from chemical exposure to offsite and noninvolved worker populations and offsite MEIs follows a similar trend, decreasing as fewer installations treat LLMW. However, both cancer fatality risks and chemical-related cancer incidence risks to the noninvolved worker MEI increase slightly (less than a factor of 2) in the Centralized Alternative (as compared with the Regionalized 2, 3, and 4 Alternatives), reflecting increased exposure of the noninvolved worker MEI with consolidation of waste and treatment at one installation.

The No Action Alternative had the highest risk of cancer fatality for the offsite and noninvolved worker MEIs (6.9E–06 and 8.7E–06, respectively). The risk of cancer from chemical exposure is about two or more orders of magnitude less than from radionuclide exposure for both MEIs. The hazard index for the offsite MEI ranges from 4.8E–09 to 2.0E–05. The hazard index for the noninvolved worker MEI ranges from 3.8E–08 to 3.7E–05. The hazard and exposure indices for all MEIs are well below 1.0 in all alternatives, indicating a low probability of adverse health effects from noncarcinogenic chemicals.

Treatment of RH-LLMW at four installations results in cancer fatality risks to the offsite and noninvolved worker MEIs of 3.4E–08 and 2.3E–08, respectively. Risks of cancer incidence from chemical exposure to both MEIs ranges from 2.9E–12 and 1.8E–11, respectively.

Workers. Total estimated risks of cancer incidence and cancer fatality to workers potentially exposed to radionuclides are very similar among alternatives, differing by less than a factor of 2. Estimated cancer fatality risks for the No Action and the CH-LLMW treatment alternatives range from 5.2E–01 to 8.4E–01 (populations ranging from 8,700 to 13,100 FTEs). Risk of cancer incidence from potential radiation exposure ranges from 1.8 to 2.9 for the same alternatives. Risks of cancer fatality and incidence to workers potentially exposed to radionuclides in the RH treatment scenario are 2.3E–02 and 8.1E–02, respectively (total worker population of 1,119 FTEs).

Worker health risks due to potential chemical exposure are also similar among alternatives (No Action and CH-LLMW treatment). The highest cancer incidence (1.8E–02 out of a total population of 8,672 FTEs) and the highest exposure index (2.6E–02) from potential chemical exposure to workers is found in the Centralized Alternative, where all waste is treated at Hanford. In this alternative, chemical waste loads are substantially larger at Hanford and more workers are processing more waste at a time to complete treatment over the 10-year period. However, risk from potential chemical exposure to workers from the Centralized Alternative is higher only by a factor of 2 over the other alternatives. For RH-LLMW, cancer incidence risk of each alternative (excluding No Action) from potential chemical exposure to workers is 6.7E–05, and the exposure index is 4.6E–04.

All worker cancer incidence risks due to potential chemical exposure are one to two orders of magnitude lower than cancer incidence risk from potential radionuclide exposure. All exposure indices are well below 1.0, indicating a low possibility for adverse health effects from potential exposure to noncarcinogenic chemicals.

Estimated construction fatality risks for CH-LLMW treatment are also very similar among alternatives, ranging from 1.4 to 2.0 (Regionalized and Centralized Alternatives). Construction fatality risks are slightly lower for the No Action Alternative (6.0E–01). Construction fatality risk associated with the RH-LLMW treatment is 2.9E–01. Risk of operational fatality ranges from 1.1 to 1.8 for the No Action and CH-LLMW treatment alternatives, and is 1.6E–01 for the RH-LLMW treatment scenario. Estimated operational fatalities are one order of magnitude lower for the No Action Alternative (2.6E–01). This is due to the less worker person-hours associated with treatment in the No Action Alternative. Estimated construction and operations injuries follow the same pattern as fatalities.

Although worker risks associated with the CH-LLMW treatment are very similar across alternatives, some differences in risk reported by installation are notable. The estimated total fatality risk (cancer, construction, and operation combined) at KCP (E–05 to E–04 range) are lower by one or more orders of magnitude. The numbers are lower because this installation has a much smaller waste load to treat and fewer workers (one or less FTE in all alternatives) than other installations. The same trend is seen for total cancer incidence from potential radionuclide and chemical exposure at KCP (see Table D.3.5–15).

The highest total fatality and cancer incidence risks associated with potential exposure to radionuclides and chemicals from the CH-LLMW treatment alternatives are at Hanford in the Centralized Alternative (2.2 and 1.8 for radionuclides and chemicals, respectively). All risks at Hanford increase about one-half to one order of magnitude in the Centralized Alternative, where Hanford is the only treatment installation.

The highest total fatality and cancer incidence risks for the RH-LLMW treatment scenario are from ORR (3.0E–01 and 7.5E–02, respectively) and INEL (1.7E–01 and 6.9E–03, respectively). This is due to much larger RH-LLMW volumes and a much larger exposed work force at the two installations (725 at ORR and 569 at INEL compared with 1 at Hanford and 17 at SRS).

D.3.5.4.2 *Programwide Trends in Human Health Risks Associated With LLMW Disposal*

In general, Regionalized 3 (single-installation disposal of CH-LLMW at NTS) poses the lowest total health risks to all farm family lifetimes for cancer fatalities and cancer incidence. Estimated risk of cancer incidence (from radiological and chemical exposure) associated with all other CH-LLMW disposal alternatives is higher by approximately 1 order of magnitude. The estimated risk of cancer incidence to all

farm family lifetimes from radionuclides ranges from zero (Regionalized 3) to 8.6E–01 (Centralized); and the estimated cancer incidence risk from carcinogenic chemicals ranges from 8.5E–03 (Centralized) to 8.3E–01 (Regionalized 2). The hazard indices (for a member of the MEL of the farm family) range from 8.1E–01 in Regionalized 3 to 3.0 in Decentralized and Regionalized 1.

Only one scenario (all alternatives except No Action) was analyzed for RH-LLMW with four installations (Hanford, INEL, ORR, and SRS) treating and disposing of all waste onsite. The risks of cancer incidence to all farm family lifetimes from radionuclides range from zero (INEL) to 4.4E–03 (ORR). The risks of cancer incidence posed by chemicals range from 2.6E–07 (Hanford) to 5.7E–04 (ORR). The hazard indices (to a member of the MEL of the farm family) range from 7.2E–5 (Hanford) to 1.3E–02 (SRS).

Maximally Exposed Lifetime of the Hypothetical Farm Family. The lowest risks of cancer incidence due to radionuclide exposure to the MEL of the farm family are for Regionalized 3 in which all LLMW is disposed of at NTS. The risk of cancer incidence is zero for the farm family of four. This lack of risk is primarily due to the greater depth of the groundwater, the small amount of rainfall, and the lack of volatile radionuclides (such as carbon-14) in the waste at NTS. This results in retarded migration of contaminants into the groundwater (slow-moving, long-lived radionuclides have not yet reached the groundwater during the 10,000-year analysis period).

The highest risks of cancer incidence due to radionuclide exposure to the MEL of the farm family are for the Centralized Alternative in which all CH-LLMW is disposed of at Hanford. The risk of cancer incidence is 6.6E–02 (average individual risk of cancer incidence is 1.7E–02) during lifetime 18 with uranium-238 as the controlling radionuclide. The elevated risks are probably due to a higher level of contaminant migration into the groundwater.

The lowest disposal installation risks are at INEL, LANL, and NTS for Decentralized and Regionalized 1, 2, and 4 and at NTS for Regionalized 3. The estimated risk of cancer incidence due to radionuclide exposure to the MEL of the farm family for each of these alternatives is zero. This is due to the lack of volatile radionuclides in the waste at installations with a greater depth to groundwater and a small amount of rainfall.

The lowest estimated risks of cancer incidence due to chemical exposure to the MEL of the farm family are for the Centralized Alternative in which CH-LLMW is disposed of at Hanford. The programwide risk of

cancer incidence is 9.5E–04 for the MEL of the farm family (individual cancer incidence risk is 2.4E–04) during lifetime 18 where 1,2-dichloroethane is the controlling contaminant.

The highest risks of cancer incidence due to chemical exposure to the MEL of the farm family are for Decentralized (15-installation disposal), Regionalized 1 (12-installation disposal), and Regionalized 2 and 4 (both 6-installation disposal). The chemical-related cancer incidence risk for each of these alternatives is very similar, ranging from 9.8E–03 to 1.3E–02. For each of these alternatives, the risk of chemical-related cancer incidence at ORR ranges from 6.4E–03 to 1.2E–02 during lifetime 61, and the controlling contaminant is 1,2-dichloroethane. The higher risk at this installation is due to a much higher concentration of volatile, potentially carcinogenic contaminants in the groundwater.

The lowest hazard index for a member of the MEL of the farm family occurs at LLNL for Decentralized and Regionalized 1 (5.5E–04) during lifetime 22. The controlling contaminant is acetone, which accounts for more than 99% of the hazard index. The hazard index is well below 1.0, therefore, exposure to noncarcinogenic, hazardous chemicals presents very few health hazards to any of the farm family lifetimes at NTS in this alternative.

The highest hazard index occurs at RFETS for Regionalized 1 (3.0) during lifetime 26. The controlling contaminant is arsenic, which accounts for over 60% of the hazard index. As this hazard index is greater than 1.0, it indicates a risk of toxicity to the maximally exposed farm family.

For RH-LLMW disposal, the lowest estimated risks of cancer incidence due to radionuclides is at INEL where the risk to the MEL of the farm family is zero. As observed for NTS, the low amount of rainfall, the depth to groundwater, and a lack of volatile radionuclides in the waste lead to a greatly reduced risk due to retarded migration of contaminants. Estimated risk of radionuclide-related cancer incidence to the MEL of the farm family is highest at ORR with a risk of 2.8E–04 (individual cancer risk of 7.0E–05) during lifetime 22, and the driving radionuclide is neptunium-237.

The lowest risks of cancer incidence posed by chemicals in RH-LLMW is at Hanford (2.6E–08) where carbon tetrachloride is the controlling contaminant during lifetime 34. The highest estimated risk of cancer incidence due to chemicals is at ORR (8.1E–06) during lifetime 61; 1,2-dichloroethane is the controlling contaminant. All hazard indices are below 1.0, indicating that adverse health effects associated with noncarcinogenic chemicals are estimated to be unlikely for RH-LLMW disposal.

Workers Placing Wastes Into Disposal. The estimated worker cancer fatality and incidence risks due to radionuclide exposure during disposal are very similar among alternatives, ranging from 3.6E–01 to 6.4E–01 and from 1.3 and 2.2, respectively, for the CH-LLMW treatment alternatives. However, the estimated risk of fatality from construction is lower for the one-installation disposal alternatives (Regionalized 3 and Centralized) than for other alternatives. Hanford and NTS are the single disposal installations in these alternatives and both have a large amount of existing disposal capacity compared to other installations; therefore, these two installations would require less construction of disposal facilities. The construction risks for the other CH-LLMW alternatives (Decentralized and Regionalized 1, 2, 4) are very similar. Construction fatality risk for the RH-LLMW disposal scenario is 3.0E–02. Trends in risk of construction injury follow those seen for risk of construction fatality.

The estimated number of operational fatalities is within an order of magnitude among the CH disposal alternatives (ranging from 3.1E–01 to 1.6). The RH disposal scenario has an estimated operational fatality risk of 2.1E–02. In general, operational fatalities are slightly higher for alternatives where multiple installations dispose (Decentralized and Regionalized 1, 2, 4) and are slightly lower where only one installation disposes (Regionalized 3 and Centralized). This trend is due to fewer total worker person-hours associated with fewer disposal installations. Risk of operational injury to workers follows the same trend as operational fatalities.

Though overall risks to workers from disposal do not differ appreciably among CH treatment alternatives, some trends are apparent among installation risks associated with disposal. In the multiple-installation disposal alternatives (Decentralized and Regionalized 1, 2, 4), the same two installations, Hanford and INEL, have the highest cancer risks by about 0.5 to 2 orders of magnitude. These installations are consolidation installations for disposal of CH-LLMW in these alternatives. The controlling contaminants are cesium-137 at Hanford for Decentralized and cobalt-60 at Hanford and INEL for Regionalized 1, 2, and 4; external radiation is the predominant exposure route. In the one-installation disposal alternatives, the controlling contaminant at Hanford in Centralized and NTS in Regionalized 3 is cobalt-60; the primary exposure route is external radiation. Risks increase approximately 3 to 5 orders of magnitude at NTS where it is the only installation disposing in Regionalized 3; and risks go up only slightly at Hanford when it is the only disposal installation in the Centralized Alternative.

For RH-LLMW disposal, estimated risk of cancer fatality and cancer incidence from radionuclide exposure are 1.5E–03 and 5.2E–03, respectively. INEL and ORR have the greatest estimated risks to workers by 2

to 7 orders of magnitude with total estimated fatalities (exposure plus physical hazards) of 2.1E–02 and 9.7E–03 and cancer incidence (from radionuclides and chemicals) of 3.5E–03 and 1.8E–03, respectively, over Hanford and SRS. This difference in risk is attributed to the large amounts of remote-handled LLMW at INEL and ORR versus the comparatively small amounts at Hanford and SRS. The controlling radionuclide at INEL and ORR is cobalt-60 and external radiation is the primary exposure route.

D.3.5.4.3 *Comparison Among Treatment Options*

A comparison of CH-LLMW treatment options (No Action and 49-, 11-, 7-, 4-, and 1-installation treatment options) indicates that treatment risks (radiological and chemical) to offsite and noninvolved worker populations generally decrease as the number of treatment installations are reduced. This trend is due in part to transfer of waste to installations where offsite populations are smaller and/or farther away from treatment facilities. Worker risks associated with treatment are very similar for all alternatives. Radiological risks associated with treatment are consistently higher than chemical exposure risks associated with treatment for all receptors.

D.3.5.4.4 *Comparison Among Disposal Scenarios*

Direct comparisons can be made between the two CH-LLMW alternatives that involve disposal at a single installation. Regionalized 3 involves disposal at NTS, and Centralized involves disposal at Hanford. The estimated risk of cancer incidence due to radionuclide exposure is higher for Hanford (6.6E–02) than for NTS (zero). The risk of cancer incidence due to exposure to carcinogenic chemicals is slightly higher at NTS than at Hanford (7.2E–04 versus 9.5E–04, respectively). However, the hazard index at Hanford is higher by approximately one order of magnitude (8.1E–01 at NTS versus 2.4 at Hanford). Though both NTS and Hanford are in arid environments, the level of the groundwater at NTS is much deeper than at Hanford, and radionuclide contaminants migrate at a much slower rate.

Comparisons can also be made between Regionalized 2 (treat CH-LLMW at seven installations, dispose at six installations) and Regionalized 4 (treat CH-LLMW at four installations, dispose at six installations). There is no appreciable difference in the estimated risk of cancer incidence due to chemicals (8.2E+01)

or in the hazard indices (2.7). The risks of cancer incidence due to radionuclides show also little variation (8.0E–02 for Regionalized 2 and 8.5E–02 for Regionalized 4).

All worker risks associated with CH-LLMW disposal are similar among alternatives.

D.3.5.4.5 *Summary of Results for Routine Treatment and Disposal of LLMW*

In summary, the No Action Alternative presents the highest treatment health risks to the offsite and noninvolved worker populations. For treatment, radiological risks are consistently higher than chemical exposure risks for all receptors.

Since the types of treatment do not change for any of the LLMW alternatives, treatment is not a consideration for LLMW disposal. The risks are largely affected by the amount and type of waste load as well as the groundwater characteristics of the disposal installation. Geographical location of the disposal installation and the characteristics of the soil affecting the migration of contaminants into the groundwater affect the risks as well.

Worker risks are very similar across all CH-LLMW alternatives, regardless of number of treatment installations or disposal scenario. However, as might be expected, consolidation of CH-LLMW at fewer installations for treatment or disposal tends to elevate worker risks at those installations.

D.3.5.5 Summary of Alternatives for Potential LLMW Accidents

The following LLMW alternatives were evaluated for potential treatment facility (incinerator) accidents: No Action, Decentralized, Regionalized 1, Regionalized 2, Regionalized 4, and Centralized. Health risks associated with accidental releases of radionuclides and those associated with accidental releases of chemicals were analyzed separately from one another and are discussed separately in this section. In addition, the risks from accidents affecting facilities that manage alpha-emitting radionuclides were analyzed separately from the accident risks for facilities that manage nonalpha-emitting radionuclides (these two categories of radionuclides are referred to as "alpha" and "nonalpha" in the analysis). Note that incineration accident scenarios postulated for Regionalized 1 only include installations with alpha facilities.

The treatment facility accidents analyzed include (1) an incinerator explosion and resulting fire; (2) a baghouse area fire; and (3) an earthquake with subsequent fire. For accidents involving chemical releases during incineration, only the feedstock staging area fire scenario is evaluated.

D.3.5.6 Special Assumptions and Considerations Used in the LLMW Accident Analysis

All accidental releases from incinerator facilities to the outside (i.e., to the offsite and noninvolved worker populations) are assumed to be at ground level with dispersion starting at a lower level rather than from a facility stack. In the incinerator explosion accident scenario, it is assumed that the efficiency of the facility's high-efficiency particulate air filtration system drops only to 99.9%. In the assessment of worker risks from incineration accidents, it is assumed that the air in the work area is not ventilated or filtered; the intrafacility source term for this accident is, therefore, 1,000 times higher than the atmospheric source term used to calculate risks to the offsite and noninvolved worker populations.

Incineration accidents are assumed to cause releases into the operating gallery where the workers are located. Half of the operating gallery (e.g., an area 32 m long × 6 m wide × 6 m high) is assumed to fill with contaminated air. Exposure duration is 1 min, the time necessary for workers to avoid any obstructions and leave the scene. During all accidents, one shift of waste management workers is assumed to be inside the incinerator facility. Shift size varies from 1 to 14 workers.

Each accident type has an associated estimated annual frequency of occurrence as determined by Argonne National Laboratory (see Section D.2.7.1). However, the probability of occurrence is not taken into account in the risk calculations. Risk estimates associated with each accident should be interpreted as the consequences if the accident occurred. Estimated annual frequencies vary by accident type and contaminant type.

For radionuclide-related accidents, the incinerator explosion is considered to be "anticipated" (greater than 1.0E-02); the feedstock staging area fire is considered "unlikely" (1.0E-04 to 1.0E-02); and the earthquake resulting in an incinerator facility fire is considered "very unlikely" (1.0E-06 to 1.0E-04). For chemical-related accidents, the incinerator feedstock staging area fire is considered "anticipated" (greater than 1.0E-02) (see Appendix F).

All "chromium" listed in the source term was assumed to be 100% chromium (VI) due to lack of more specific information. This is a conservative assumption, and health risks associated with chromium (VI) may be overestimated.

D.3.5.7 Results Tables for the Risk Analysis of Potential LLMW Accidents

Because of the volume of results tables for potential LLMW accidents, the following results tables are presented on the following pages.

- Tables D.3.5–37 and D.3.5–38 present the maximum reasonably foreseeable radionuclide- and chemical-related accidents for the offsite and noninvolved worker populations, their respective MEIs, and waste management workers for treatment facility accidents, by installation and alternative.
- Tables D.3.5–39 through D.3.5–70 present the radionuclide-related risks associated with LLMW treatment for the offsite population, offsite MEI, and worker population by alternative, installation, and accident type.
- Tables D.3.5–71 through D.3.5–113 present the chemical-related risks associated with LLMW treatment for the offsite population, offsite MEI, and worker population by alternative, installation, and accident type.

While the risk analysis results for the noninvolved worker population and noninvolved worker MEI are discussed below, the risk results for these receptors are not included in Tables D.3.5–39 through D.3.5–113.

Table D.3.5–37. Radionuclide-Related Risks From Potential Maximum Reasonably Foreseeable LLMW Treatment Facility Accidents, by Alternative and Site

Site	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI		Worker Population	
	CF	CI	CF	CI	CF	CI	CF	CI	CF	CI
No Action										
INEL	1.3E-03	4.4E-03	1.5E-07	5.0E-07	7.2E-04	2.4E-03	4.3E-07	1.5E-06	1.4E-04	5.0E-04
ORR	1.6E-01	5.5E-01	1.4E-05	4.7E-05	8.3E-02	2.8E-01	9.2E-05	3.1E-04	9.8E-03	3.4E-02
SRS	2.0E-02	6.7E-02	6.1E-07	2.1E-06	2.2E-03	7.3E-03	9.4E-06	3.2E-05	3.2E-03	1.1E-02
Decentralized										
ANL-E	9.4E-04	3.2E-03	2.8E-08	9.5E-08	1.2E-05	4.2E-05	9.1E-08	3.1E-07	2.1E-06	9.5E-06
BNL	1.0E-02	3.5E-02	9.2E-07	3.1E-06	8.1E-05	2.8E-04	7.5E-07	2.5E-06	9.3E-06	3.2E-05
FEMP	1.6E-05	5.4E-05	4.1E-09	1.4E-08	5.9E-07	2.0E-06	4.0E-09	1.3E-08	7.0E-08	2.5E-07
Hanford	2.7E-01	9.1E-01	6.3E-06	2.1E-05	2.2E-02	7.5E-02	2.2E-04	7.6E-04	1.1E-02	3.8E-02
INEL	2.1E-03	7.1E-03	2.4E-07	8.1E-07	2.0E-03	6.8E-03	1.2E-06	4.1E-06	3.1E-03	1.1E-02
KAPL-K	4.1E-03	1.4E-02	2.1E-07	7.0E-07	6.9E-05	2.4E-04	2.8E-07	9.5E-07	5.7E-06	2.0E-05
LANL	9.1E-04	3.1E-03	4.3E-07	1.5E-06	2.6E-04	8.8E-04	7.7E-07	2.6E-06	1.7E-04	6.0E-04
LLNL	1.1E-02	3.8E-02	1.6E-06	5.3E-06	9.5E-04	3.2E-03	1.7E-06	5.6E-06	1.3E-04	4.7E-04
ORR	1.6E-01	5.5E-01	1.4E-05	4.7E-05	8.3E-02	2.8E-01	9.2E-05	3.1E-04	1.1E-02	3.9E-02
PGDP	3.1E-02	1.1E-01	9.0E-06	3.1E-05	6.1E-03	2.1E-02	5.4E-05	1.8E-04	2.3E-03	8.2E-03
Pantex	5.1E-04	1.7E-03	5.6E-08	1.9E-07	1.1E-05	3.7E-05	1.9E-07	6.4E-07	5.2E-06	1.8E-05
RFETS	5.9E-03	2.0E-02	2.1E-07	7.1E-07	1.0E-03	3.5E-03	3.1E-06	1.0E-05	3.9E-04	1.4E-03
SRS	2.0E-02	6.7E-02	6.1E-07	2.1E-06	2.2E-03	7.3E-03	9.4E-06	3.2E-05	3.2E-03	1.1E-02
Regionalized 1										
INEL	2.1E-03	7.1E-03	2.4E-07	8.1E-07	2.0E-03	6.8E-03	1.2E-06	4.1E-06	3.1E-03	1.1E-02
LANL	9.1E-04	3.1E-03	4.3E-07	1.5E-06	2.6E-04	8.8E-04	7.7E-07	2.6E-06	1.7E-04	6.0E-04
LLNL	1.1E-02	3.8E-02	1.6E-06	5.3E-06	9.5E-04	3.2E-03	1.7E-06	5.6E-06	1.3E-04	4.7E-04
RFETS	5.9E-03	2.0E-02	2.1E-07	7.1E-07	1.0E-03	3.5E-03	3.1E-06	1.0E-05	3.9E-04	1.4E-03
SRS	1.7E-03	5.9E-03	5.3E-08	1.8E-07	1.9E-04	6.5E-04	8.2E-07	2.8E-06	1.4E-04	4.9E-04
Regionalized 2										
Hanford	2.7E-01	9.1E-01	6.3E-06	2.1E-05	2.2E-02	7.5E-02	2.2E-04	7.6E-04	1.1E-02	3.8E-02
INEL	2.1E-03	7.1E-03	2.4E-07	8.1E-07	2.0E-03	6.9E-03	1.2E-06	4.1E-06	3.1E-03	1.1E-02
LANL	9.1E-04	3.1E-03	4.3E-07	1.5E-06	2.6E-04	8.8E-04	7.7E-07	2.6E-06	1.7E-04	6.0E-04
ORR	1.8E-01	6.1E-01	1.5E-05	5.1E-05	1.2E-01	4.2E-01	1.4E-04	4.6E-04	1.6E-02	5.7E-02
RFETS	5.9E-03	2.0E-02	2.1E-07	7.1E-07	1.0E-03	3.5E-03	3.1E-06	1.0E-05	3.9E-04	1.4E-03
SRS	2.0E-02	6.7E-02	6.1E-07	2.1E-06	2.2E-03	7.4E-03	9.4E-06	3.2E-05	3.2E-03	1.1E-02

Table D.3.5–37. Radionuclide-Related Risks From Potential Maximum Reasonably Foreseeable LLMW Treatment Facility Accidents, by Alternative and Site—Continued

Site	Offsite Population		Offsite MEI		Noninvolved Worker Population		Noninvolved Worker MEI		Worker Population	
	CF	CI	CF	CI	CF	CI	CF	CI	CF	CI
Regionalized 4										
Hanford	2.7E-01	9.1E-01	6.3E-06	2.1E-05	2.2E-02	7.5E-02	2.2E-04	7.6E-04	1.1E-02	3.8E-02
INEL	2.1E-03	7.1E-03	2.4E-07	8.1E-07	2.0E-03	6.9E-03	1.2E-06	4.1E-06	3.5E-03	1.2E-02
ORR	1.8E-01	6.2E-01	1.6E-05	5.3E-05	9.6E-02	3.3E-01	1.1E-04	3.6E-04	1.4E-02	5.0E-02
SRS	2.0E-02	6.7E-02	6.1E-07	2.1E-06	2.2E-03	7.4E-03	9.4E-06	3.2E-05	3.2E-03	1.1E-02
Centralized										
Hanford	4.0E-01	1.4	9.4E-06	3.2E-05	3.8E-02	1.3E-01	3.9E-04	1.3E-03	4.4E-02	1.6E-01

Notes: ME = Maximally exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at a site; CF = risk of cancer fatality associated with exposure to radionuclides; CI = risk of cancer incidence associated with exposure to radionuclides.

Table D.3.5–38. Chemical-Related Risks From Potential Maximum Reasonably Foreseeable LLMW Treatment Facility Accidents, by Alternative and Site

Site	Offsite Population	Offsite MEI		Noninvolved Worker Population	Noninvolved Worker MEI		Workers	
	CI	CI	HI	CI	CI	HI	CI	IDLH
No Action								
INEL	8.9E-07	2.1E-10	3.5E-03	2.0E-06	1.2E-09	1.9E-02	7.5E-08	1.1
ORR	7.3E-03	4.7E-07	7.8	6.3E-04	5.0E-07	8.1	1.9E-04	3.0E+01
SRS	1.5E-05	4.9E-09	8.1E-02	6.9E-05	2.7E-07	4.4	6.0E-05	1.4E+01
Decentralized								
ANL-E	5.4E-05	1.5E-11	2.8E-04	8.0E-09	4.4E-11	8.2E-04	4.3E-09	1.0
BNL	3.2E-05	5.8E-10	9.5E-03	2.4E-08	1.9E-10	3.1E-03	1.8E-08	1.0
FEMP	2.3E-04	1.0E-08	1.6E-01	1.5E-06	9.6E-09	1.6E-01	2.1E-06	1.9
Hanford	6.5E-05	1.7E-09	2.8E-02	3.4E-07	9.1E-09	1.5E-01	2.1E-05	5.3
INEL	3.5E-05	8.2E-09	1.3E-01	7.9E-05	4.5E-08	7.4E-01	1.9E-05	4.7
KCP	2.7E-07	1.2E-11	2.0E-04	3.4E-09	1.2E-11	2.0E-04	7.7E-12	1.0
KAPL-K	3.6E-06	6.1E-10	1.0E-02	1.5E-07	6.1E-10	1.0E-02	9.3E-09	1.0
LANL	2.2E-05	7.5E-09	1.2E-01	4.3E-06	5.8E-08	9.4E-01	4.5E-06	2.6
LBL	5.6E-06	5.1E-10	8.4E-03	1.4E-07	5.3E-10	8.7E-03	3.9E-09	1.0
LLNL	8.8E-05	2.4E-08	4.0E-01	2.0E-05	3.4E-08	5.6E-01	6.0E-06	3.2
ORR	8.7E-03	5.6E-07	9.2	7.5E-04	5.9E-07	9.6	2.5E-04	3.6E+01
PGDP	1.3E-04	1.9E-08	3.2E-01	1.4E-06	1.2E-08	1.9E-01	9.9E-07	1.8
Pantex	6.5E-06	4.5E-10	7.4E-03	7.8E-07	8.6E-09	1.4E-01	7.0E-07	1.9

Table D.3.5-38. Chemical-Related Risks From Potential Maximum Reasonably Foreseeable LLMW Treatment Facility Accidents, by Alternative and Site—Continued

Site	Offsite Population	Offsite MEI		Noninvolved Worker Population	Noninvolved Worker MEI		Workers	
	CI	CI	HI	CI	CI	HI	CI	IDLH
Decentralized (Cont.)								
PORTS	1.1E-04	7.9E-08	1.3	4.6E-05	1.3E-07	2.1	3.4E-05	9.5
RFETS	4.7E-04	9.5E-09	1.6E-01	4.6E-06	1.2E-08	1.9E-01	4.5E-06	1.8
SNL-NM	3.5E-06	1.0E-09	1.7E-02	3.6E-07	1.0E-09	1.7E-02	4.6E-08	1.1
SRS	1.6E-05	5.2E-09	8.5E-02	7.3E-05	2.8E-07	4.7	5.9E-05	1.4E+01
Regionalized 1								
FEMP	2.5E-04	1.1E-08	1.8E-01	1.6E-06	1.1E-08	1.7E-01	3.8E-06	2.0
Hanford	6.6E-05	1.7E-09	2.8E-02	3.5E-07	9.3E-09	1.5E-01	2.2E-05	5.4
INEL	3.5E-05	8.2E-09	1.3E-01	7.9E-05	4.5E-08	7.4E-01	1.9E-05	4.7
LANL	2.2E-05	7.5E-09	1.2E-01	4.3E-06	5.8E-08	9.4E-01	4.5E-06	2.6
LLNL	9.1E-05	2.5E-08	4.1E-01	2.1E-05	3.6E-08	5.8E-01	6.4E-06	3.3
ORR	8.7E-03	5.6E-07	9.2	7.6E-04	5.9E-07	9.6	2.5E-04	3.6E+01
PGDP	1.3E-04	1.9E-08	3.2E-01	1.4E-06	1.2E-08	1.9E-01	9.9E-07	1.8
Pantex	6.5E-06	4.5E-10	7.4E-03	7.8E-07	8.6E-09	1.4E-01	7.0E-07	1.9
PORTS	1.1E-04	8.1E-08	1.3	4.7E-05	1.3E-07	2.2	3.5E-05	9.8
RFETS	4.7E-04	9.5E-09	1.6E-01	4.6E-06	1.2E-08	1.9E-01	4.5E-06	1.8
SRS	1.6E-05	5.2E-09	8.6E-02	7.3E-05	2.9E-07	4.7	5.9E-05	1.4E+01
Regionalized 2								
Hanford	1.0E-04	2.6E-09	4.3E-02	5.3E-07	1.4E-08	2.3E-01	3.4E-05	7.7
INEL	5.0E-05	1.2E-08	1.9E-01	1.1E-04	6.6E-08	1.1	3.1E-05	6.3
LANL	2.2E-05	7.5E-09	1.2E-01	4.3E-06	5.8E-08	9.4E-01	4.5E-06	2.6
ORR	8.9E-03	5.7E-07	9.4	7.6E-04	6.0E-07	9.8	2.5E-04	3.6E+01
PORTS	1.2E-04	9.0E-08	1.5	5.2E-05	1.5E-07	2.4	4.7E-05	1.1E+01
RFETS	4.7E-04	9.5E-09	1.6E-01	4.6E-06	1.2E-08	1.9E-01	4.5E-06	1.8
SRS	1.6E-05	5.2E-09	8.6E-02	7.3E-05	2.9E-07	4.7	5.9E-05	1.4E+01
Regionalized 4								
Hanford	1.0E-04	2.6E-09	4.3E-02	5.3E-07	1.4E-08	2.3E-01	3.2E-05	7.7
INEL	7.2E-05	1.7E-08	2.8E-01	1.7E-04	9.5E-08	1.6	4.9E-05	8.7
ORR	1.1E-02	7.3E-07	1.2E+01	9.7E-04	7.7E-07	1.3E+01	3.6E-04	4.6E+01
SRS	1.6E-05	5.2E-09	8.6E-02	7.3E-05	2.9E-07	4.7	6.4E-05	1.4E+01
Centralized								
Hanford	1.0E-03	2.6E-08	4.3E-01	5.2E-06	1.4E-07	2.3	7.5E-04	6.8E+01

Notes: MEI = Maximally exposed individual; each value represents the highest *single* risk (not the sum of all risks) to the MEI from among all accidents at a site; CI = risk of cancer incidence associated with exposure to carcinogenic chemicals; HI = hazard index; IDLH = worker IDLH index.

Table D.3.5-39. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, incinerator explosion (A)[c]	7.8E-07	8.9E-11	8.6E-05	2.7E-06	3.0E-10	3.0E-04
Non-alpha incineration, baghouse area fire (U)	2.0E-05	2.2E-09	2.1E-06	6.6E-05	7.6E-09	7.5E-06
Non-alpha incineration, earthquake (VU)	1.3E-03	1.5E-07	1.4E-04	4.4E-03	5.0E-07	5.0E-04
Maximum reasonably foreseeable accident	1.3E-03	1.5E-07	1.4E-04	4.4E-03	5.0E-07	5.0E-04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-40. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, incinerator explosion (A)[c]	1.6E-01	1.4E-05	9.8E-03	5.5E-01	4.7E-05	3.4E-02
Non-alpha incineration, baghouse area fire (U)	9.7E-05	8.2E-09	5.9E-03	3.3E-04	2.8E-08	2.1E-02
Non-alpha incineration, earthquake (VU)	2.4E-03	2.1E-07	1.5E-04	8.2E-03	7.0E-07	5.1E-04
Maximum reasonably foreseeable accident	1.6E-01	1.4E-05	9.8E-03	5.5E-01	4.7E-05	3.4E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-41. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, (A)[c] incinerator explosion	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02
Non-alpha incineration, (U) baghouse area fire	1.2E-05	3.6E-10	1.9E-03	4.0E-05	1.2E-09	6.7E-03
Non-alpha incineration, (VU) earthquake	3.0E-04	9.1E-09	4.8E-05	1.0E-03	3.1E-08	1.7E-04
Maximum reasonably foreseeable accident	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-42. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, (A)[c] incinerator explosion	5.6E-07	1.7E-11	1.6E-06	1.9E-06	5.7E-11	5.7E-06
Non-alpha incineration, (U) baghouse area fire	1.2E-07	3.6E-12	3.5E-10	4.1E-07	1.2E-11	1.2E-09
Non-alpha incineration, (VU) earthquake	9.4E-04	2.8E-08	2.7E-06	3.2E-03	9.5E-08	9.5E-06
Maximum reasonably foreseeable accident	9.4E-04	2.8E-08	2.7E-06	3.2E-03	9.5E-08	9.5E-06

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-43. Radionuclide-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, (A)[c] incinerator explosion	6.1E-06	5.5E-10	5.6E-06	2.1E-05	1.9E-09	1.9E-05
Non-alpha incineration, (U) baghouse area fire	1.5E-04	1.4E-08	1.4E-07	5.2E-04	4.7E-08	4.9E-07
Non-alpha incineration, (VU) earthquake	1.0E-02	9.2E-07	9.3E-06	3.5E-02	3.1E-06	3.2E-05
Maximum reasonably foreseeable accident	1.0E-02	9.2E-07	9.3E-06	3.5E-02	3.1E-06	3.2E-05

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-44. Radionuclide-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, (A)[c] incinerator explosion	1.6E-05	4.1E-09	7.0E-08	5.4E-05	1.4E-08	2.5E-07
Non-alpha incineration, (U) baghouse area fire	9.5E-09	2.5E-12	4.2E-08	3.2E-08	8.4E-12	1.5E-07
Non-alpha incineration, (VU) earthquake	2.4E-07	6.2E-11	1.1E-09	8.1E-07	2.1E-10	3.7E-09
Maximum reasonably foreseeable accident	1.6E-05	4.1E-09	7.0E-08	5.4E-05	1.4E-08	2.5E-07

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–45. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, incinerator explosion (A)[c]	2.7E-01	6.3E-06	1.1E-02	9.1E-01	2.1E-05	3.8E-02
Non-alpha incineration, baghouse area fire (U)	1.6E-04	3.8E-09	6.5E-03	5.5E-04	1.3E-08	2.3E-02
Non-alpha incineration, earthquake (VU)	4.0E-03	9.5E-08	1.6E-04	1.4E-02	3.2E-07	5.7E-04
Maximum reasonably foreseeable accident	2.7E-01	6.3E-06	1.1E-02	9.1E-01	2.1E-05	3.8E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (< 1.0E-06).

Table D.3.5–46. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	2.1E-03	2.4E-07	3.1E-03	7.1E-03	8.1E-07	1.1E-02
Alpha incineration, incinerator explosion (A)	1.3E-06	1.4E-10	1.8E-03	4.3E-06	4.9E-10	6.4E-03
Alpha incineration, baghouse area fire (U)	3.1E-05	3.6E-09	4.6E-05	1.1E-04	1.2E-08	1.6E-04
Non-alpha incineration, earthquake (VU)	1.3E-03	1.5E-07	1.4E-04	4.5E-03	5.1E-07	5.1E-04
Non-alpha incineration incinerator explosion (A)	7.9E-07	9.0E-11	8.7E-05	2.7E-06	3.1E-10	3.0E-04
Non-alpha incineration, baghouse area fire (U)	2.0E-05	2.3E-09	2.2E-06	6.7E-05	7.7E-09	7.6E-06
Maximum reasonably foreseeable accident	2.1E-03	2.4E-07	3.1E-03	7.1E-03	8.1E-07	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (< 1.0E-06).

Table D.3.5-47. Radionuclide-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, (VU)[c] earthquake	4.1E-03	2.1E-07	5.7E-06	1.4E-02	7.0E-07	2.0E-05
Non-alpha incineration, (A) incinerator explosion	2.5E-06	1.2E-10	3.4E-06	8.4E-06	4.2E-10	1.2E-05
Non-alpha incineration, (U) baghouse area fire	6.2E-05	3.1E-09	8.6E-08	2.1E-04	1.1E-08	3.0E-07
Maximum reasonably foreseeable accident	4.1E-03	2.1E-07	5.7E-06	1.4E-02	7.0E-07	2.0E-05

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (< 1.0E-06).

Table D.3.5-48. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (VU)[c] earthquake	1.1E-02	1.6E-06	1.3E-04	3.8E-02	5.3E-06	4.7E-04
Alpha incineration, (A) incinerator explosion	6.8E-06	9.3E-10	8.0E-05	2.3E-05	3.2E-09	2.8E-04
Alpha incineration, (U) baghouse area fire	1.7E-04	2.3E-08	2.0E-06	5.8E-04	7.9E-08	7.0E-06
Maximum reasonably foreseeable accident	1.1E-02	1.6E-06	1.3E-04	3.8E-02	5.3E-06	4.7E-04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (< 1.0E-06).

Table D.3.5–49. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	9.1E-04	4.3E-07	1.7E-04	3.1E-03	1.5E-06	6.0E-04
Alpha incineration, incinerator explosion (A)	5.4E-07	2.6E-10	1.0E-04	1.9E-06	8.8E-10	3.6E-04
Alpha incineration, baghouse area fire (U)	1.4E-05	6.5E-09	2.6E-06	4.6E-05	2.2E-08	9.0E-06
Maximum reasonably foreseeable accident	9.1E-04	4.3E-07	1.7E-04	3.1E-03	1.5E-06	6.0E-04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–50. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	1.6E-01	1.4E-05	1.1E-02	5.5E-01	4.7E-05	3.9E-02
Alpha incineration, incinerator explosion (A)	9.7E-05	8.2E-09	6.6E-03	3.3E-04	2.8E-08	2.3E-02
Alpha incineration, baghouse area fire (U)	2.4E-03	2.1E-07	1.7E-04	8.2E-03	7.0E-07	5.8E-04
Maximum reasonably foreseeable accident	1.6E-01	1.4E-05	1.1E-02	5.5E-01	4.7E-05	3.9E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-51. Radionuclide-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	3.1E-02	9.0E-06	2.3E-03	1.1E-01	3.1E-05	8.2E-03
Alpha incineration, incinerator explosion (A)	1.9E-05	5.4E-09	1.4E-03	6.3E-05	1.8E-08	4.9E-03
Alpha incineration, baghouse area fire (U)	4.6E-04	1.4E-07	3.5E-05	1.6E-03	4.6E-07	1.2E-04
Maximum reasonably foreseeable accident	3.1E-02	9.0E-06	2.3E-03	1.1E-01	3.1E-05	8.2E-03

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-52. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	5.1E-04	5.6E-08	5.2E-06	1.7E-03	1.9E-07	1.8E-05
Alpha incineration, incinerator explosion (A)	3.1E-07	3.3E-11	3.1E-06	1.0E-06	1.1E-10	1.1E-05
Alpha incineration, baghouse area fire (U)	7.7E-06	8.3E-10	7.8E-08	2.6E-05	2.8E-09	2.7E-07
Maximum reasonably foreseeable accident	5.1E-04	5.6E-08	5.2E-06	1.7E-03	1.9E-07	1.8E-05

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-53. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	5.9E-03	2.1E-07	3.9E-04	2.0E-02	7.1E-07	1.4E-03
Alpha incineration, incinerator explosion (A)	3.5E-06	1.3E-10	2.4E-04	1.2E-05	4.3E-10	8.3E-04
Alpha incineration, baghouse area fire (U)	8.8E-05	3.1E-09	5.9E-06	3.0E-04	1.1E-08	2.1E-05
Maximum reasonably foreseeable accident	5.9E-03	2.1E-07	3.9E-04	2.0E-02	7.1E-07	1.4E-03

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-54. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	1.7E-03	5.3E-08	1.4E-04	5.9E-03	1.8E-07	4.9E-04
Alpha incineration, incinerator explosion (A)	1.0E-06	3.2E-11	8.4E-05	3.5E-06	1.1E-10	2.9E-04
Alpha incineration, baghouse area fire (U)	2.6E-05	8.0E-10	2.1E-06	8.8E-05	2.7E-09	7.3E-06
Non-alpha incineration, earthquake (VU)	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02
Non-alpha incineration, incinerator explosion (A)	1.2E-05	3.6E-10	1.9E-03	4.0E-05	1.2E-09	6.7E-03
Non-alpha incineration, baghouse area fire (U)	3.0E-04	9.1E-09	4.8E-05	1.0E-03	3.1E-08	1.7E-04
Maximum reasonably foreseeable accident	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-55. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (A) incinerator explosion	1.3E-06	1.4E-10	1.8E-03	4.3E-06	4.9E-10	6.4E-03
Alpha incineration, (U) baghouse area fire	3.1E-05	3.6E-09	4.6E-05	1.1E-04	1.2E-08	1.6E-04
Alpha incineration, (VU) earthquake	2.1E-03	2.4E-07	3.1E-03	7.1E-03	8.1E-07	1.1E-02
Maximum reasonably foreseeable accident	2.1E-03	2.4E-07	3.1E-03	7.1E-03	8.1E-07	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-56. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LLNL Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (VU)[c] earthquake	1.1E-02	1.6E-06	1.3E-04	3.8E-02	5.3E-06	4.7E-04
Alpha incineration (A) incinerator explosion	6.8E-06	9.3E-10	8.0E-05	2.3E-05	3.2E-09	2.8E-04
Alpha incineration, (U) baghouse area fire	1.7E-04	2.3E-08	2.0E-06	5.8E-04	7.9E-08	7.0E-06
Maximum reasonably foreseeable accident	1.1E-02	1.6E-06	1.3E-04	3.8E-02	5.3E-06	4.7E-04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-57. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under the Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (VU)[c] earthquake	9.1E-04	4.3E-07	1.7E-04	3.1E-03	1.5E-06	6.0E-04
Alpha incineration, (A) incinerator explosion	5.4E-07	2.6E-10	1.0E-04	1.9E-06	8.8E-10	3.6E-04
Alpha incineration, (U) baghouse area fire	1.4E-05	6.5E-09	2.6E-06	4.6E-05	2.2E-08	9.0E-06
Maximum reasonably foreseeable accident	9.1E-04	4.3E-07	1.7E-04	3.1E-03	1.5E-06	6.0E-04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-58. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (VU)[c] earthquake	5.9E-03	2.1E-07	3.9E-04	2.0E-02	7.1E-07	1.4E-03
Alpha incineration, (A) incinerator explosion	3.5E-06	1.3E-10	2.4E-04	1.2E-05	4.3E-10	8.3E-04
Alpha incineration, (U) baghouse area fire	8.8E-05	3.1E-09	5.9E-06	3.0E-04	1.1E-08	2.1E-05
Maximum reasonably foreseeable accident	5.9E-03	2.1E-07	3.9E-04	2.0E-02	7.1E-07	1.4E-03

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–59. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (VU)[c] earthquake	1.7E–03	5.3E–08	1.4E–04	5.9E–03	1.8E–07	4.9E–04
Alpha incineration, (A) incinerator explosion	1.0E–06	3.2E–11	8.4E–05	3.5E–06	1.1E–10	2.9E–04
Alpha incineration, (U) baghouse area fire	2.6E–05	8.0E–10	2.1E–06	8.8E–05	2.7E–09	7.3E–06
Maximum reasonably foreseeable accident	1.7E–03	5.3E–08	1.4E–04	5.9E–03	1.8E–07	4.9E–04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (< 1.0E–06).

Table D.3.5–60. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, (VU)[c] earthquake	2.7E–01	6.3E–06	1.1E–02	9.1E–01	2.1E–05	3.8E–02
Non-alpha incineration, (A) incinerator explosion	1.6E–04	3.8E–09	6.5E–03	5.5E–04	1.3E–08	2.3E–02
Non-alpha incineration, (U) baghouse area fire	4.0E–03	9.5E–08	1.6E–04	1.4E–02	3.2E–07	5.7E–04
Maximum reasonably foreseeable accident	2.7E–01	6.3E–06	1.1E–02	9.1E–01	2.1E–05	3.8E–02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (< 1.0E–06).

Table D.3.5-61. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, incinerator explosion (A)[c]	1.3E-06	1.4E-10	1.8E-03	4.3E-06	4.9E-10	6.4E-03
Alpha incineration, baghouse area fire (U)	3.1E-05	3.6E-09	4.6E-05	1.1E-04	1.2E-08	1.6E-04
Non-alpha incineration, incinerator explosion (A)	7.9E-07	9.0E-11	1.7E-04	2.7E-06	3.1E-10	6.1E-04
Non-alpha incineration, baghouse area fire (U)	2.0E-05	2.3E-09	4.3E-06	6.7E-05	7.7E-09	1.5E-05
Alpha incineration, earthquake (VU)	2.1E-03	2.4E-07	3.1E-03	7.1E-03	8.1E-07	1.1E-02
Non-alpha incineration, earthquake (VU)	1.3E-03	1.5E-07	2.9E-04	4.5E-03	5.1E-07	1.0E-03
Maximum reasonably foreseeable accident	2.1E-03	2.4E-07	3.1E-03	7.1E-03	8.1E-07	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-62. Radionuclide-Related Accident Risks Associated With LLMW Treatment at LANL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, incinerator explosion (A)[c]	5.4E-07	2.6E-10	1.0E-04	1.9E-06	8.8E-10	3.6E-04
Alpha incineration, baghouse area fire (U)	1.4E-05	6.5E-09	2.6E-06	4.6E-05	2.2E-08	9.0E-06
Non-alpha incineration, incinerator explosion (A)	4.8E-04	2.3E-07	9.3E-06	1.7E-03	7.8E-07	3.3E-05
Non-alpha incineration, baghouse area fire (U)	2.9E-07	1.4E-10	5.6E-06	9.9E-07	4.7E-10	2.0E-05
Alpha incineration, earthquake (VU)	7.3E-06	3.5E-09	1.4E-07	2.5E-05	1.2E-08	4.9E-07
Non-alpha incineration, earthquake (VU)	9.1E-04	4.3E-07	1.7E-04	3.1E-03	1.5E-06	6.0E-04
Maximum reasonably foreseeable accident	9.1E-04	4.3E-07	1.7E-04	3.1E-03	1.5E-06	6.0E-04

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-63. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, earthquake (VU)[c]	1.8E-01	1.5E-05	1.6E-02	6.1E-01	5.1E-05	5.7E-02
Non-alpha incineration, incinerator explosion (A)	1.1E-04	9.0E-09	9.8E-03	3.6E-04	3.1E-08	3.4E-02
Non-alpha incineration, baghouse area fire (U)	2.7E-03	2.3E-07	2.4E-04	9.1E-03	7.6E-07	8.5E-04
Maximum reasonably foreseeable accident	1.8E-01	1.5E-05	1.6E-02	6.1E-01	5.1E-05	5.7E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-64. Radionuclide-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-Alpha incineration, (VU)[c] earthquake	1.5E-04	5.5E-09	4.0E-07	5.3E-04	1.9E-08	1.4E-06
Alpha incineration, (A) incinerator explosion	3.5E-06	1.3E-10	2.4E-04	1.2E-05	4.3E-10	8.3E-04
Alpha incineration, (U) baghouse area fire	8.8E-05	3.1E-09	5.9E-06	3.0E-04	1.1E-08	2.1E-05
Alpha incineration, (VU) earthquake	5.9E-03	2.1E-07	3.9E-04	2.0E-02	7.1E-07	1.4E-03
Non-alpha incineration, (A) incinerator explosion	9.3E-08	3.3E-12	2.4E-07	3.2E-07	1.1E-11	8.5E-07
Non-alpha incineration, (U) baghouse area fire	2.3E-06	8.3E-11	6.0E-09	7.9E-06	2.8E-10	2.1E-08
Maximum reasonably foreseeable accident	5.9E-03	2.1E-07	3.9E-04	2.0E-02	7.1E-07	1.4E-03

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-65. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	1.7E-03	5.3E-08	1.4E-04	5.9E-03	1.8E-07	4.9E-04
Alpha incineration, incinerator explosion (A)	1.0E-06	3.2E-11	8.4E-05	3.5E-06	1.1E-10	2.9E-04
Alpha incineration, baghouse area fire (U)	2.6E-05	8.0E-10	2.1E-06	8.8E-05	2.7E-09	7.3E-06
Non-alpha incineration, earthquake (VU)	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02
Non-alpha incineration, incinerator explosion (A)	1.2E-05	3.7E-10	1.9E-03	4.0E-05	1.3E-09	6.7E-03
Non-alpha incineration, baghouse area fire (U)	3.0E-04	9.2E-09	4.8E-05	1.0E-03	3.1E-08	1.7E-04
Maximum reasonably foreseeable accident	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-66. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, earthquake (VU)[c]	2.7E-01	6.3E-06	1.1E-02	9.1E-01	2.1E-05	3.8E-02
Non-alpha incineration, incinerator explosion (A)	1.6E-04	3.8E-09	6.5E-03	5.5E-04	1.3E-08	2.3E-02
Non-alpha incineration, baghouse area fire (U)	4.0E-03	9.5E-08	1.6E-04	1.4E-02	3.2E-07	5.7E-04
Maximum reasonably foreseeable accident	2.7E-01	6.3E-06	1.1E-02	9.1E-01	2.1E-05	3.8E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-67. Radionuclide-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	2.1E-03	2.4E-07	3.5E-03	7.1E-03	8.1E-07	1.2E-02
Alpha incineration, incinerator explosion (A)	1.3E-06	1.4E-10	2.1E-03	4.3E-06	4.9E-10	7.4E-03
Alpha incineration, baghouse area fire (U)	3.1E-05	3.6E-09	5.3E-05	1.1E-04	1.2E-08	1.9E-04
Non-alpha incineration, earthquake (VU)	1.3E-03	1.5E-07	4.4E-04	4.5E-03	5.1E-07	1.5E-03
Non-alpha incineration, incinerator explosion (A)	7.9E-07	9.0E-11	2.6E-04	2.7E-06	3.1E-10	9.1E-04
Non-alpha incineration, baghouse area fire (U)	2.0E-05	2.3E-09	6.5E-06	6.7E-05	7.7E-09	2.3E-05
Maximum reasonably foreseeable accident	2.1E-03	2.4E-07	3.5E-03	7.1E-03	8.1E-07	1.2E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-68. Radionuclide-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Non-alpha incineration, earthquake (VU)[c]	1.8E-01	1.6E-05	1.4E-02	6.2E-01	5.3E-05	5.0E-02
Non-alpha incineration, incinerator explosion (A)	1.1E-04	9.4E-09	8.5E-03	3.7E-04	3.2E-08	3.0E-02
Non-alpha incineration, baghouse area fire (U)	2.8E-03	2.3E-07	2.1E-04	9.3E-03	8.0E-07	7.4E-04
Maximum reasonably foreseeable accident	1.8E-01	1.6E-05	1.4E-02	6.2E-01	5.3E-05	5.0E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-69. Radionuclide-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, (VU)[c] earthquake	1.7E-03	5.3E-08	1.4E-04	5.9E-03	1.8E-07	4.9E-04
Alpha incineration, (A) incinerator explosion	1.0E-06	3.2E-11	8.4E-05	3.5E-06	1.1E-10	2.9E-04
Alpha incineration, (U) baghouse area fire	2.6E-05	8.0E-10	2.1E-06	8.8E-05	2.7E-09	7.3E-06
Non-alpha incineration, (VU) earthquake	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02
Non-alpha incineration, (A) incinerator explosion	1.2E-05	3.7E-10	1.9E-03	4.0E-05	1.3E-09	6.7E-03
Non-alpha incineration, (U) baghouse area fire	3.0E-04	9.2E-09	4.8E-05	1.0E-03	3.1E-08	1.7E-04
Maximum reasonably foreseeable accident	2.0E-02	6.1E-07	3.2E-03	6.7E-02	2.1E-06	1.1E-02

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (> 1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (< 1.0E-06).

Table D.3.5–70. Radionuclide-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type

Accident	Cancer Fatalities[a]			Cancer Incidence[b]		
	Offsite Population	Offsite MEI	Workers	Offsite Population	Offsite MEI	Workers
Alpha incineration, earthquake (VU)[c]	3.4E–03	8.0E–08	4.5E–04	1.2E–02	2.7E–07	1.6E–03
Non-alpha incineration, earthquake (VU)	4.0E–01	9.4E–06	4.4E–02	1.4	3.2E–05	1.6E–01
Non-alpha incineration, incinerator explosion (A)	2.4E–04	5.7E–09	2.7E–02	8.2E–04	1.9E–08	9.3E–02
Non-alpha incineration, baghouse area fire (U)	6.0E–03	1.4E–07	6.7E–04	2.1E–02	4.8E–07	2.3E–03
Alpha incineration, incinerator explosion (A)	2.0E–06	4.8E–11	2.7E–04	6.9E–06	1.6E–10	9.4E–04
Alpha incineration, baghouse area fire (U)	5.1E–05	1.2E–09	6.7E–06	1.7E–04	4.1E–09	2.4E–05
Maximum reasonably foreseeable accident	4.0E–01	9.4E–06	4.4E–02	1.4	3.2E–05	1.6E–01

[a] Indicates cancer fatalities associated with radiation exposure.
[b] Indicates cancer incidence associated with radiation exposure.
[c] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–71. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the No Action Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	8.9E–07	2.1E–10	7.5E–08	3.5E–03	1.1
Maximum reasonably foreseeable accident	8.9E–07	2.1E–10	7.5E–08	3.5E–03	1.1

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–72. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the No Action Alternative, by Accident Type

Accident		Cancer Incidence[a]			Hazard Index	IDLH Index
		Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-Alpha incineration, baghouse area fire	(A)[b]	7.3E-03	4.7E-07	1.9E-04	7.8	3.0E+01
Maximum reasonably foreseeable accident		7.3E-03	4.7E-07	1.9E-04	7.8	3.0E+01

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–73. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the No Action Alternative, by Accident Type

Accident		Cancer Incidence[a]			Hazard Index	IDLH Index
		Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire	(A)[b]	1.5E-05	4.9E-09	6.0E-05	8.1E-02	1.4E+01
Maximum reasonably foreseeable accident		1.5E-05	4.9E-09	6.0E-05	8.1E-02	1.4E+01

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–74. Chemical-Related Accident Risks Associated With LLMW Treatment at ANL-E Under the Decentralized Alternative, by Accident Type

Accident		Cancer Incidence[a]			Hazard Index	IDLH Index
		Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire	(A)[b]	5.4E-07	1.5E-11	4.3E-09	2.8E-04	1.0
Maximum reasonably foreseeable accident		5.4E-07	1.5E-11	4.3E-09	2.8E-04	1.0

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-75. Chemical-Related Accident Risks Associated With LLMW Treatment at BNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, (A)[b] baghouse area fire	3.2E-05	5.8E-10	1.8E-08	9.5E-03	1.0
Maximum reasonably foreseeable accident	3.2E-05	5.8E-10	1.8E-08	9.5E-03	1.0

[a] Indicates cancer incidence associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-76. Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, (A)[b] baghouse area fire	2.3E-04	1.0E-08	2.1E-06	1.6E-01	1.9
Maximum reasonably foreseeable accident	2.3E-04	1.0E-08	2.1E-06	1.6E-01	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-77. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, (A)[b] baghouse area fire	6.5E-05	1.7E-09	2.1E-05	2.8E-02	5.3
Maximum reasonably foreseeable accident	6.5E-05	1.7E-09	2.1E-05	2.8E-02	5.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-78. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	2.8E-06	6.8E-10	3.1E-07	1.1E-02	1.3
Alpha incineration, baghouse area fire (A)	3.5E-05	8.2E-09	1.9E-05	1.3E-01	4.7
Maximum reasonably foreseeable accident	3.5E-05	8.2E-09	1.9E-05	1.3E-01	4.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
b Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-79. Chemical-Related Accident Risks Associated With LLMW Treatment at KCP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	2.7E-07	1.2E-11	7.7E-12	2.0E-04	1.0
Maximum reasonably foreseeable accident	2.7E-07	1.2E-11	7.7E-12	2.0E-04	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-80. Chemical-Related Accident Risks Associated With LLMW Treatment at KAPL-K Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	3.6E-06	6.1E-10	9.3E-09	1.0E-02	1.0
Maximum reasonably foreseeable accident	3.6E-06	6.1E-10	9.3E-09	1.0E-02	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-81. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	2.6E-06	8.7E-10	7.9E-08	1.4E-02	1.2
Alpha incineration, baghouse area fire (A)	2.2E-05	7.5E-09	4.5E-06	1.2E-01	2.6
Maximum reasonably foreseeable accident	2.2E-05	7.5E-09	4.5E-06	1.2E-01	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-82. Chemical-Related Accident Risks Associated With LLMW Treatment at LBL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	5.6E-06	5.1E-10	3.9E-09	8.4E-03	1.0
Maximum reasonably foreseeable accident	5.6E-06	5.1E-10	3.9E-09	8.4E-03	1.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-83. Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	8.8E-05	2.4E-08	6.0E-06	4.0E-01	3.2
Alpha incineration, baghouse area fire (A)	6.4E-05	1.8E-08	4.7E-06	2.9E-01	2.6
Maximum reasonably foreseeable accident	8.8E-05	2.4E-08	6.0E-06	4.0E-01	3.2

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–84. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	8.7E–03	5.6E–07	2.5E–04	9.2	3.6E+01
Maximum reasonably foreseeable accident	8.7E–03	5.6E–07	2.5E–04	9.2	3.6E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (< 1.0E–06).

Table D.3.5–85. Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	1.3E–04	1.9E–08	9.9E–07	3.2E–01	1.8
Maximum reasonably foreseeable accident	1.3E–04	1.9E–08	9.9E–07	3.2E–01	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (< 1.0E–06).

Table D.3.5–86. Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	6.5E–06	4.5E–10	7.0E–07	7.4E–03	1.9
Maximum reasonably foreseeable accident	6.5E–06	4.5E–10	7.0E–07	7.4E–03	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (> 1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (< 1.0E–06).

Table D.3.5–87. Chemical-Related Accident Risks Associated With LLMW Treatment at PORTS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Worker
Non-alpha incineration, baghouse area fire (A)[b]	1.1E-04	7.9E-08	3.4E-05	1.3	9.5
Maximum reasonably foreseeable accident	1.1E-04	7.9E-08	3.4E-05	1.3	9.5

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–88. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Alpha incineration, baghouse area fire (A)[b]	4.7E-04	9.5E-09	4.5E-06	1.6E-01	1.8
Maximum reasonably foreseeable accident	4.7E-04	9.5E-09	4.5E-06	1.6E-01	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–89. Chemical-Related Accident Risks Associated With LLMW Treatment at SNL-NM Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	3.5E-06	1.0E-09	4.6E-08	1.7E-02	1.1
Maximum reasonably foreseeable accident	3.5E-06	1.0E-09	4.6E-08	1.7E-02	1.1

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-90. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under the Decentralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.6E-05	5.2E-09	5.9E-05	8.5E-02	1.4E+01
Alpha incineration, (A) baghouse area fire	1.5E-06	4.7E-10	3.2E-06	7.6E-03	2.2
Maximum reasonably foreseeable accident	1.6E-05	5.2E-09	5.9E-05	8.5E-02	1.4E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-91. Chemical-Related Accident Risks Associated With LLMW Treatment at FEMP Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	2.5E-04	1.1E-08	3.8E-06	1.8E-01	2.0
Maximum reasonably foreseeable accident	2.5E-04	1.1E-08	3.8E-06	1.8E-01	2.0

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-92. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	6.6E-05	1.7E-09	2.2E-05	2.8E-02	5.4
Maximum reasonably foreseeable accident	6.6E-05	1.7E-09	2.2E-05	2.8E-02	5.4

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-93. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	2.8E-06	6.8E-10	3.1E-07	1.1E-02	1.3
Alpha incineration, baghouse area fire (A)	3.5E-05	8.2E-09	1.9E-05	1.3E-01	4.7
Maximum reasonably foreseeable accident	3.5E-05	8.2E-09	1.9E-05	1.3E-01	4.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-94. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	3.4E-06	1.2E-09	1.1E-07	1.9E-02	1.3
Alpha incineration, (A) baghouse area fire	2.2E-05	7.5E-09	4.5E-06	1.2E-01	2.6
Maximum reasonably foreseeable accident	2.2E-05	7.5E-09	4.5E-06	1.2E-01	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-95. Chemical-Related Accident Risks Associated With LLMW Treatment at LLNL Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	9.1E-05	2.5E-08	6.4E-06	4.1E-01	3.3
Alpha incineration, (A) baghouse area fire	6.4E-05	1.8E-08	4.7E-06	2.9E-01	2.6
Maximum reasonably foreseeable accident	9.1E-05	2.5E-08	6.4E-06	4.1E-01	3.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-96. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	8.7E-03	5.6E-07	2.5E-04	9.2	3.6E+01
Maximum reasonably foreseeable accident	8.7E-03	5.6E-07	2.5E-04	9.2	3.6E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-97. Chemical-Related Accident Risks Associated With LLMW Treatment at Pantex Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	6.5E-06	4.5E-10	7.0E-07	7.4E-03	1.9
Maximum reasonably foreseeable accident	6.5E-06	4.5E-10	7.0E-07	7.4E-03	1.9

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5–98. Chemical-Related Accident Risks Associated With LLMW Treatment at PGDP Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	1.3E-04	1.9E-08	9.9E-07	3.2E-01	1.8
Maximum reasonably foreseeable accident	1.3E-04	1.9E-08	9.9E-07	3.2E-01	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–99. Chemical-Related Accident Risks Associated With LLMW Treatment at PORTS Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	1.1E-04	8.1E-08	3.5E-05	1.3	9.8
Maximum reasonably foreseeable accident	1.1E-04	8.1E-08	3.5E-05	1.3	9.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–100. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	2.1E–07	4.2E–12	2.7E–12	6.9E–05	1.0
Alpha incineration, (A) baghouse area fire	4.7E–04	9.5E–09	4.5E–06	1.6E–01	1.8
Maximum reasonably foreseeable accident	4.7E–04	9.5E–09	4.5E–06	1.6E–01	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–101. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 1, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.6E–05	5.2E–09	5.9E–05	8.6E–02	1.4E+01
Alpha incineration, (A) baghouse area facility fire	1.5E–06	4.7E–10	3.2E–06	7.6E–03	2.2
Maximum reasonably foreseeable accident	1.6E–05	5.2E–09	5.9E–05	8.6E–02	1.4E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–102. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.0E–04	2.6E–09	3.4E–05	4.3E–02	7.7
Maximum reasonably foreseeable accident	1.0E–04	2.6E–09	3.4E–05	4.3E–02	7.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5–103. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	2.9E–06	7.0E–10	5.2E–07	1.1E–02	1.3
Alpha incineration, (A) baghouse area fire	5.0E–05	1.2E–08	3.1E–05	1.9E–01	6.3
Maximum reasonably foreseeable accident	5.0E–05	1.2E–08	3.1E–05	1.9E–01	6.3

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E–02), "U" for unlikely (1.0E–04 to 1.0E–02), "VU" for very unlikely (1.0E–06 to 1.0E–04), and "EU" for extremely unlikely (<1.0E–06).

Table D.3.5-104. Chemical-Related Accident Risks Associated With LLMW Treatment at LANL Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.6E-05	5.5E-09	1.2E-06	9.0E-02	2.2
Alpha incineration, (A) baghouse area fire	2.2E-05	7.5E-09	4.5E-06	1.2E-01	2.6
Maximum reasonably foreseeable accident	2.2E-05	7.5E-09	4.5E-06	1.2E-01	2.6

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-105. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration (A)[b] baghouse area fire	8.9E-03	5.7E-07	2.5E-04	9.4	3.6E+01
Maximum reasonably foreseeable accident	8.9E-03	5.7E-07	2.5E-04	9.4	3.6E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-106. Chemical-Related Accident Risks Associated With LLMW Treatment at PORTS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.2E-04	9.0E-08	4.7E-05	1.5	1.1E+01
Maximum reasonably foreseeable accident	1.2E-04	9.0E-08	4.7E-05	1.5	1.1E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-107. Chemical-Related Accident Risks Associated With LLMW Treatment at RFETS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	8.0E-07	1.6E-11	2.1E-11	2.6E-04	1.0
Alpha incineration, (A) baghouse area fire	4.7E-04	9.5E-09	4.5E-06	1.6E-01	1.8
Maximum reasonably foreseeable accident	4.7E-04	9.5E-09	4.5E-06	1.6E-01	1.8

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-108. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 2, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.6E-05	5.2E-09	5.9E-05	8.6E-02	1.4E+01
Alpha incineration, (A) baghouse area fire	1.5E-06	4.7E-10	3.2E-6	7.6E-03	2.2
Maximum reasonably foreseeable accident	1.6E-05	5.2E-09	5.9E-05	8.6E-02	1.4E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-109. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, (A)[b] baghouse area fire	1.0E-04	2.6E-09	3.2E-05	4.3E-02	7.7
Maximum reasonably foreseeable accident	1.0E-04	2.6E-09	3.2E-05	4.3E-02	7.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-110. Chemical-Related Accident Risks Associated With LLMW Treatment at INEL Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	1.4E-05	3.4E-09	3.6E-06	5.5E-02	2.5
Alpha incineration, baghouse area fire (A)	7.2E-05	1.7E-08	4.9E-05	2.8E-01	8.7
Maximum reasonably foreseeable accident	7.2E-05	1.7E-08	4.9E-05	2.8E-01	8.7

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-111. Chemical-Related Accident Risks Associated With LLMW Treatment at ORR Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	1.1E-02	7.3E-07	3.6E-04	1.2E+01	4.6E+01
Maximum reasonably foreseeable accident	1.1E-02	7.3E-07	3.6E-04	1.2E+01	4.6E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-112. Chemical-Related Accident Risks Associated With LLMW Treatment at SRS Under Regionalized Alternative 4, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	1.6E-05	5.2E-09	6.4E-05	8.6E-02	1.4E+01
Alpha incineration, baghouse area fire (A)	1.5E-06	4.7E-10	3.8E-06	7.6E-03	2.2
Maximum reasonably foreseeable accident	1.6E-05	5.2E-09	6.4E-05	8.6E-02	1.4E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

Table D.3.5-113. Chemical-Related Accident Risks Associated With LLMW Treatment at Hanford Under the Centralized Alternative, by Accident Type

Accident	Cancer Incidence[a]			Hazard Index	IDLH Index
	Offsite Population	Offsite MEI	Workers	Offsite MEI	Workers
Non-alpha incineration, baghouse area fire (A)[b]	1.0E-03	2.6E-08	7.5E-04	4.3E-01	6.8E+01
Alpha incineration, baghouse area fire (A)	1.3E-04	3.5E-09	5.7E-05	5.7E-02	9.8
Maximum reasonably foreseeable accident	1.0E-03	2.6E-08	7.5E-04	4.3E-01	6.8E+01

[a] Indicates cancer fatalities associated with chemical carcinogen exposure.
[b] Accident annual frequency codes are "A" for anticipated (>1.0E-02), "U" for unlikely (1.0E-04 to 1.0E-02), "VU" for very unlikely (1.0E-06 to 1.0E-04), and "EU" for extremely unlikely (<1.0E-06).

D.3.5.8 Summary of the LLMW Accident Analysis Results

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related incineration accidents in all alternatives, the dominant accident type for all receptors is the earthquake resulting in a fire. The highest site-specific cancer fatality risks are consistently associated with Hanford and/or ORR for all receptors. Cancer fatality risks associated with incineration accidents in alpha facilities are usually higher than those associated with similar accidents in non-alpha facilities by 2 times to 3 orders of magnitude (for all receptors at INEL, LANL, and RFETS in Decentralized, Regionalized 2, and Regionalized 4). However, at SRS (in all alternatives where SRS is evaluated) and at Hanford (in the Centralized Alternative), alpha facility accident risks are lower than those from similar accidents in non-alpha facilities by 1 to 2 orders of magnitude. Note that for workers, the risk of death from latent cancers due to exposure to radioactive materials released in such accidents may be smaller than the risk of fatality due to nonradiological impacts.

Accidents Involving Releases of Chemical Contaminants. For chemical-related incineration accidents in all alternatives except Centralized (where Hanford treats all LLMW), ORR is consistently the highest-risk site for all receptors. In the Centralized Alternative, however, Hanford has the highest worker cancer incidence risk and IDLH index of all alternatives due to a greater number of exposed workers. At sites where both alpha and non-alpha LLMW are incinerated, the accident risks vary depending on contaminant inventories. At a given site, the estimated cancer incidence risks and hazard/IDLH indices for accidents occurring in alpha incineration facilities are usually higher (in some instances by more than 2 orders of magnitude) than those estimated for similar non-alpha facility accidents. The exceptions to this are: SRS (Decentralized and Regionalized 1, 2, and 4) and Hanford (Centralized), where the risks from non-alpha incineration accidents are approximately one order of magnitude higher than those from alpha facility accidents; and LLNL (Decentralized and Regionalized 1), where non-alpha incineration accident risks are only slightly higher (less than a factor of two) than similar alpha facility accident risks.

D.3.5.8.1 *Risks to the Offsite Population From LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For incineration accidents involving releases of radionuclides from non-alpha facilities, cancer fatality risks to the offsite population range from 9.5E-09 to 4.0E-01 in population sizes ranging from 153,061 to 10,453,402. Cancer fatality risks from alpha

facility incinerator accidents range from 5.4E–07 to 1.1E–02 in population sizes ranging from 153,061 to 6,324,234. Incineration accident risks at a given site do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at a site across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to offsite populations is the earthquake resulting in a fire. In each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and aircraft impact) are approximately 2 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given site. However, the estimated annual frequency of the earthquake scenario affecting the incinerator facility is "very unlikely" (1.0E–06 to 1.0E–04) for all sites and alternatives, while the baghouse area fire and incinerator explosion are considered "unlikely" (1.0E–04 to 1.0E–02) and "anticipated" (greater than 1.0E–02), respectively. Hanford has the highest cancer fatality risks to the offsite population from incineration accidents in all alternatives (where Hanford is evaluated) because of relatively high releases of plutonium-238 and/or uranium-238. The highest cancer fatality risk at Hanford is 4.0E–1 (distributed over a population of 377,645) for the non-alpha earthquake scenario in the Centralized Alternative. ORR has the next highest cancer fatality risks to the offsite population from non-alpha incineration accidents. The controlling contaminant at ORR is uranium-238. Internal exposure is the primary route for both sites. The highest alpha facility accident risks are at LLNL in Decentralized and Regionalized 1 and at RFETS in Decentralized and Regionalized 1 and 2. The controlling contaminant at both sites is plutonium-238; the primary exposure route is internal.

Accidents Involving Releases of Chemical Contaminants. For incineration accidents that involve chemical releases from non-alpha facilities (baghouse area fire), the estimated risks of cancer incidence range from 2.1E–07 to 1.1E–02 in population sizes ranging from 153,061 to 10,453,402. Estimated risks of cancer incidence from alpha incinerator facility baghouse area fire accidents range from 1.5E–06 to 4.7E–04 in population sizes ranging from 153,061 to 6,324,234. All chemical-related baghouse area fire scenarios are considered "anticipated" (estimated annual frequency greater than 1.0E–02).

The highest estimated risk of cancer incidence from an accidental chemical release associated with incineration at a site is at ORR in Regionalized 4 (1.1E–02 in a population of 881,652). In all alternatives except Centralized (in which all treatment is performed at Hanford), ORR poses the greatest risks of cancer incidence from incineration accidents, ranging from 7.3E–03 to 1.1E–02 in a population of 881,652. This is approximately 1 to 5 orders of magnitude higher than the risks at all other sites. The higher estimated

cancer risk at ORR is due to a relatively large release of chromium (VI) during an incinerator accident. The alpha incineration accident with the highest risk of cancer incidence to the offsite population is the baghouse area fire at RFETS; the risk of cancer incidence is 4.7E–04 in a population of 2,171,877 for Decentralized and Regionalized 1 and 2. The controlling contaminant at RFETS is also chromium (VI).

Maximum reasonably foreseeable incineration accident risks do not differ much among alternatives at most sites (remain approximately equal or increase slightly with greater waste consolidation). However, cancer incidence risk to the offsite population from the maximum reasonably foreseeable accident in Decentralized and Regionalized 1, 2, and 4 is higher than for No Action at INEL by 1 to 2 orders of magnitude. In addition, cancer incidence risk from the worst-case accident at Hanford in the Centralized Alternative is higher than for Hanford in other alternatives by an order of magnitude or more due to centralized consolidation of waste loads.

D.3.5.8.2 *Risks to the Noninvolved Worker Population From LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related accidents, the trends in risk to the noninvolved worker population follow the trends for the offsite population. For incineration accidents involving releases of radionuclides from non-alpha facilities, cancer fatality risks range from 3.5E–10 to 1.2E–01 in population sizes ranging from 128 to 15,996. Cancer fatality risks from alpha facility incinerator accidents range from 1.1E–07 to 2.0E–03 in population sizes ranging from 6,993 to 15,996. Incineration accident risks at a given site do not differ greatly among alternatives. Risks associated with a particular accident either remain the same at a site across alternatives or increase only slightly with waste consolidation.

The incineration accident type resulting in the highest risks to noninvolved worker populations is the earthquake resulting in a fire. For each alternative, the risks of cancer fatalities for other incinerator accidents (incinerator explosion and aircraft impact) are approximately 1 to 3 orders of magnitude lower than those associated with the earthquake scenario at a given site. Recall, however, that the estimated annual frequency of the earthquake scenario affecting the incinerator facility is the lowest of the three accident types.

For the non-alpha facility earthquake scenario, ORR produces the greatest risk of cancer fatalities, with the maximum reasonably foreseeable accident risks ranging from 8.3E–02 to 1.2E–01 in Decentralized and Regionalized 2 and 4, distributed over a population of 3,809. The next highest non-alpha accident risks are at Hanford in all alternatives (where Hanford is evaluated), with cancer fatality risks ranging from 2.2E–02 to 3.8E–02 in a population of 8,674. The controlling contaminants at ORR and Hanford are uranium-238 and plutonium-238, respectively. For alpha facility incinerator accidents, the highest-risk sites are INEL and RFETS in Decentralized and Regionalized 1 and 2 and INEL in Regionalized 4. In these alternatives, cancer fatality risk associated with the incinerator accident (earthquake) is 2.0E–03 for INEL in a population of 8,451 and 1.0E–03 for RFETS in a population of 6,993; the controlling contaminant is plutonium-238 at both sites.

Accidents Involving Releases of Chemical Contaminants. For chemical-related incineration accidents occurring in non-alpha facilities, the estimated risks of cancer incidence range from 5.1E–10 to 9.7E–04 in population sizes ranging from 128 to 15,996. Estimated risks of cancer incidence from alpha facility incinerator accidents range from 4.3E–06 to 1.7E–04 in population sizes ranging from 6,993 to 15,996. The incinerator accident resulting in the highest estimated risk of cancer incidence is the non-alpha baghouse area fire at ORR in Regionalized 4 (9.7E–04 in a population of 3,809). In all alternatives except Centralized (all sites treat at Hanford), ORR poses the greatest risks of cancer incidence. Incineration accident risks to noninvolved worker populations at other sites are 1 to 6 orders of magnitude lower. The controlling contaminant at ORR is chromium (VI). The alpha incineration accident with the highest risk of cancer incidence to the noninvolved worker population is the baghouse area fire at INEL in Regionalized 4 (1.7E–04 in a population of 8,451). The controlling contaminant at INEL is also chromium (VI).

Maximum reasonably foreseeable accident risks of cancer incidence do not differ much among alternatives at most sites (remain approximately equal or increase slightly with greater waste consolidation). However, cancer incidence risk to the noninvolved worker population from the worst-case accident in Decentralized and Regionalized 1, 2, and 4 is higher than for No Action at INEL by 1 to 2 orders of magnitude. In addition, cancer incidence risk from the maximum reasonably foreseeable accident at Hanford in the Centralized Alternative is higher than for Hanford in other alternatives by about an order of magnitude due to centralized consolidation of waste loads.

D.3.5.8.3 *Risks to the Maximally Exposed Noninvolved Worker and Maximally Exposed Offsite Individual From LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For radionuclide-related accidents, the trends in risk to the offsite MEI and noninvolved worker MEI generally follow those for their respective populations. Incineration accident risks at a given site do not differ greatly among alternatives. Risks to the MEIs associated with a particular accident either remain the same at a site across alternatives or increase only slightly with waste consolidation. Differences in cancer risks between non-alpha facility accidents and alpha facility accidents parallel those estimated for the offsite and noninvolved worker populations.

The highest-risk incineration accident type for both MEIs is the earthquake resulting in a fire. The highest-risk sites for the offsite MEI differ somewhat from those observed for the offsite population. The highest site-specific cancer fatality risk to the offsite MEI is from the non-alpha facility earthquake scenario at ORR in No Action, Decentralized, and Regionalized 2 and 4 (ranging from 1.4E–05 to 1.6E–05). The controlling contaminant at ORR is uranium-238; the primary exposure route is internal. The next highest site risks are for the non-alpha facility earthquake scenarios at Hanford in Centralized (9.4E–06) and PGDP in Decentralized (9.0E–06). The controlling contaminants at Hanford and PGDP are plutonium-238 and uranium-238, respectively; exposure is primarily internal.

The highest cancer fatality risk to the noninvolved worker MEI from an earthquake scenario is at Hanford (for non-alpha facilities) in Decentralized, Regionalized 2 and 4, and Centralized (ranging from 2.2E–04 to 3.9E–04). The contaminant contributing the most to risk at Hanford is plutonium-238 by internal exposure. The next highest risk to the noninvolved worker MEI is from the non-alpha earthquake scenario at ORR in Regionalized 2 and 4 (1.4E–04 and 1.1E–04 cancer fatalities, respectively). The controlling contaminant at ORR is uranium-238; exposure is primarily internal.

Accidents Involving Releases of Chemical Contaminants. For chemical-related accidents, the trends in risks to the offsite MEI and the noninvolved worker MEI tend to generally follow those for their respective populations. As observed for the offsite and noninvolved worker populations, risks and hazard indices do not differ greatly among alternatives at a site with the exception of INEL (lower in No Action than other alternatives by about 2 orders of magnitude) and Hanford (greater in the Centralized Alternative with centralized consolidation by an order of magnitude or more). For incineration accidents (i.e., baghouse area fire), the highest risks of cancer incidence to the offsite MEI (7.3E–07) and the noninvolved worker MEI

(7.7E-07) occur at ORR in Regionalized 4. The cancer incidence risks to both MEIs are higher at ORR than those at other sites by 2 times to 4 orders of magnitude. The controlling carcinogenic contaminant at ORR is chromium (VI).

The highest hazard indices associated with incineration accidents are also at ORR in all alternatives (ranging from 7.8 to 1.2E+01 for the offsite MEI and from 8.1 to 1.3E+01 for the noninvolved worker MEI). For both MEIs, the hazard index is greater than 1.0 at PORTS in Decentralized and Regionalized 1 and 2 (ranging from 1.3 to 1.5 for the offsite MEI and from 2.1 to 2.4 for the noninvolved worker MEI). In addition, for the noninvolved worker MEI, hazard indices are greater than 1.0 at SRS in all alternatives where SRS treats LLMW (ranging from 4.4 to 4.7) and at INEL in Regionalized 2 and 4 (ranging from 1.1 to 1.6). The controlling noncarcinogenic chemical is hydrogen chloride at ORR, PORTS, SRS, and INEL. All other hazard indices are below 1.0, indicating less likelihood of harmful effects from exposure to noncarcinogens.

D.3.5.8.4 *Risks to Waste Management Workers From LLMW Accidents*

Accidents Involving Releases of Radiological Contaminants. For incineration accidents involving releases of radionuclides, site-specific worker risks are similar among alternatives, increasing only very slightly at sites where LLMW is consolidated for treatment, most notably in the Centralized Alternative, in which estimated cancer fatalities at Hanford from all incineration accidents increase approximately half an order of magnitude. Estimated worker cancer fatalities associated with accident scenarios in non-alpha facilities range from 7.9E-08 to 1.6E-02. For alpha facility accident scenarios, estimated worker cancer fatalities range from 1.3E-04 to 3.5E-03. Shift size varies from 1 to 14 workers. In all alternatives, the earthquake and incinerator explosion scenarios produce the higher worker risks by about 1 to 2 orders of magnitude over the baghouse area fire scenario.

The highest site-specific cancer fatality risks associated with non-alpha incinerator accidents are for the earthquake scenarios at ORR in No Action (9.8E-03), at ORR and Hanford in Decentralized (1.1E-02 at both sites), at ORR and Hanford in Regionalized 2 (1.6E-02 and 1.1E-02, respectively), at ORR and Hanford in Regionalized 4 (1.4E-02 and 1.1E-02, respectively), and at Hanford in the Centralized Alternative (4.4E-02). The controlling contaminants are uranium-238 at ORR and plutonium-238 at Hanford; the primary exposure route is inhalation. For alpha incinerator accidents, the highest site cancer

fatality risks are for the earthquake scenario at INEL in Decentralized and Regionalized 1, 2, and 4 (ranging from 3.1E–03 to 3.5E–03). The controlling contaminant at this site is plutonium-238, and the primary exposure route is inhalation. Recall that the radionuclide-related earthquake scenario affecting the incinerator is considered to be "very unlikely."

Accidents Involving Releases of Chemical Contaminants. Estimated risks of cancer incidence to workers from non-alpha incineration accidents (baghouse area fires) range from 2.7E–12 to 7.5E–04 across alternatives. Alpha facility accident risks range from 3.2E–06 to 5.7E–05. Worker population size (shift size) varies from 1 to 14 workers. Chemical emissions from an incinerator baghouse area fire in a non-alpha facility are assumed to be identical regardless of site or alternative; the same assumption was made for alpha facility accidents. Because of this, cancer incidence risk estimates for workers only vary by facility type and in direct proportion to the number of workers assumed to be present during the accident at each site (which depends on the waste volume being incinerated at each site).

The highest cancer incidence risk to workers from a non-alpha incinerator baghouse area fire is at Hanford in the Centralized Alternative (7.5E–04) due to the consolidated waste load and a greater number of workers necessary to operate the incinerator. The next highest cancer incidence risks to workers from non-alpha baghouse area fires are at ORR in all alternatives where ORR treats LLMW (ranging from 1.9E–04 to 3.6E–04). The highest alpha facility risks are also associated with Hanford in the Centralized Alternative (5.7E–05). The IDLH index is equal to or greater than 1.0 for all sites and alternatives, indicating a danger of irreversible health effects due to exposure to toxic chemicals. The controlling contaminants are the same at each site, chromium (VI) and carbon monoxide.

As observed for the offsite and noninvolved worker populations and their respective MEIs, risks and IDLH indices do not differ greatly among alternatives at a site with the exception of INEL (lower in No Action than other alternatives by about 2 orders of magnitude) and Hanford (greater in the Centralized Alternative with waste consolidation by an order of magnitude or more).

D.3.5.9 Risks to the Hypothetical Intruder From LLMW Disposal

The health risks to the hypothetical intruder who drills a well through an LLMW disposal facility were evaluated for the Decentralized, Regionalized 2, and Centralized Alternatives, and for remote-handled LLMW (RH-LLMW) disposal (disposal at four sites in the Decentralized, Regionalized, and Centralized

Alternatives). Intrusion was evaluated 100 years and 300 years after the cessation of disposal activities at each site.

Tables D.3.5-114 and D.3.5-115 present summaries of the risk evaluations at 100 and 300 years, respectively. Tables D.3.5-116 through D.3.5-123 contain the health risks by health endpoint and site for each alternative in both time frames.

Table D.3.5-114. Summary Table for the Intruder Scenario for LLMW (100 years)

Alternative	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Decentralized	34	1.7E-02	5.8E-02	3.4E-03	1.8E-13	1.1E-07
Regionalized 2	33	1.6E-02	5.5E-02	3.3E-03	1.8E-13	1.4E-07
Centralized	7.1	3.6E-03	1.2E-02	7.1E-04	5.1E-14	9.6E-08
RH-LLMW	68	3.3E-02	1.2E-01	6.8E-03	1.2E-14	8.8E-09

Table D.3.5-115. Summary Table for the Intruder Scenario for LLMW (300 years)

Alternative	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Decentralized	7.2E-01	3.5E-04	1.2E-03	7.2E-05	1.8E-13	1.1E-07
Regionalized 2	6.1E-01	3.0E-04	1.0E-03	6.1E-05	1.8E-13	1.4E-07
Centralized	1.5E-01	7.3E-05	2.5E-04	1.5E-05	5.1E-14	9.6E-08
RH-LLMW	2.2	1.1E-03	3.7E-03	2.2E-04	1.2E-14	8.8E-09

Table D.3.5-116. Intruder Scenario Risk Results for the Decentralized Alternative (100 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
ANL-E	6.6E-01	3.3E-04	1.1E-03	6.6E-05	1.4E-14	1.6E-08
BNL	1.5E-02	7.4E-06	2.5E-05	1.5E-06	0.0	1.3E-09
FEMP	1.4E-03	6.8E-07	2.3E-06	1.4E-07	0.0	6.8E-09
Hanford	19	9.4E-03	3.2E-02	1.9E-03	3.1E-14	4.0E-08
INEL	7.5	3.8E-03	1.3E-02	7.5E-04	2.2E-14	6.2E-08
LANL	5.2E-02	2.6E-05	8.8E-05	5.2E-06	0.0	1.0E-08
LLNL	3.2E-01	1.6E-04	5.4E-04	3.2E-05	0.0	1.6E-08
NTS	4.9E-02	2.4E-05	8.3E-05	4.9E-06	0.0	6.7E-09
ORR	2.6	1.3E-03	4.4E-03	2.6E-04	4.8E-14	1.1E-07
PGDP	1.3E-01	6.4E-05	2.2E-04	1.3E-05	0.0	2.5E-09
Pantex	1.9E-02	9.4E-06	3.2E-05	1.9E-06	0.0	8.6E-10
PORTS	4.8E-01	2.4E-04	8.2E-04	4.8E-05	2.7E-14	2.9E-08
RFETS	1.6E-02	7.8E-06	2.6E-05	1.6E-06	1.3E-14	5.4E-09
SNL-NM	1.1E-02	5.6E-06	1.9E-05	1.1E-06	0.0	4.9E-11
SRS	3.1	1.6E-03	5.4E-03	3.1E-04	2.8E-14	1.0E-07
Total	34	1.7E-02	5.8E-02	3.4E-03	1.8E-13	1.1E-07

Table D.3.5–117. Intruder Scenario Risk Results for the Decentralized Alternative (300 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
ANL-E	2.3E-02	1.1E-05	3.9E-05	2.3E-06	1.4E-14	1.6E-08
BNL	5.0E-04	2.5E-07	8.6E-07	5.0E-08	0.0	1.3E-09
FEMP	1.4E-03	6.8E-07	2.3E-06	1.4E-07	0.0	6.8E-09
Hanford	1.5E-01	7.7E-05	2.6E-04	1.5E-05	3.1E-14	4.0E-08
INEL	2.5E-01	1.2E-04	4.2E-04	2.5E-05	2.2E-14	6.2E-08
LANL	1.9E-03	9.3E-07	3.2E-06	1.9E-07	0.0	1.0E-08
LLNL	9.3E-03	4.6E-06	1.6E-05	9.3E-07	0.0	1.6E-08
NTS	3.1E-03	1.6E-06	5.3E-06	3.1E-07	0.0	6.7E-09
ORR	8.5E-02	4.2E-05	1.4E-04	8.5E-06	4.8E-14	1.1E-07
PGDP	1.3E-01	6.4E-05	2.2E-04	1.3E-05	0.0	2.5E-09
Pantex	1.9E-04	9.3E-08	3.2E-07	1.9E-08	0.0	8.6E-10
PORTS	6.0E-03	3.0E-06	1.0E-05	6.0E-07	2.7E-14	2.9E-08
RFETS	1.1E-02	5.7E-06	1.9E-05	1.1E-06	1.3E-14	5.4E-09
SNL-NM	1.6E-04	8.2E-08	2.8E-07	1.6E-08	0.0	4.9E-11
SRS	4.6E-02	2.3E-05	7.9E-05	4.6E-06	2.8E-14	1.0E-07
Total	7.2E-01	3.5E-04	1.2E-03	7.2E-05	1.8E-13	1.1E-07

Table D.3.5–118. Intruder Scenario Risk Results for Regionalized Alternative 2 (100 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	19	9.4E-03	3.2E-02	1.9E-03	3.4E-14	4.7E-08
INEL	7.9	3.9E-03	1.3E-02	7.9E-04	2.7E-14	6.9E-08
LANL	4.6E-02	2.3E-05	7.9E-05	4.6E-06	1.7E-14	1.1E-08
NTS	1.4E-04	7.1E-08	2.4E-07	1.4E-08	0.0	2.8E-12
ORR	2.5	1.2E-03	4.2E-03	2.5E-04	7.1E-14	1.4E-07
SRS	3.1	1.6E-03	5.4E-03	3.1E-04	2.7E-14	1.0E-07
Total	33	1.6E-02	5.5E-02	3.3E-03	1.8E-13	1.4E-07

Table D.3.5-119. Intruder Scenario Risk Results for Regionalized Alternative 2 (300 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	1.4E-01	7.1E-05	2.4E-04	1.4E-05	3.4E-14	4.7E-08
INEL	2.6E-01	1.3E-04	4.4E-04	2.6E-05	2.7E-14	6.9E-08
LANL	1.4E-02	6.8E-06	2.3E-05	1.4E-06	1.7E-14	1.1E-08
NTS	3.4E-04	1.7E-08	5.8E-08	3.4E-09	0.0	2.8E-12
ORR	1.5E-01	7.4E-05	2.5E-04	1.5E-05	7.1E-14	1.4E-07
SRS	4.6E-02	2.3E-05	7.9E-05	4.6E-06	2.7E-14	1.0E-07
Total	6.1E-01	3.0E-04	1.0E-03	6.1E-05	1.8E-13	1.4E-07

Table D.3.5-120. Intruder Scenario Risk Results for the Centralized Alternative (100 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	7.1	3.6E-03	1.2E-02	7.1E-04	5.1E-14	9.6E-08
Total	7.1	3.6E-03	1.2E-02	7.1E-04	5.1E-14	9.6E-08

Table D.3.5-121. Intruder Scenario Risk Results for the Centralized Alternative (300 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	1.5E-01	7.3E-05	2.5E-04	1.5E-05	5.1E-14	9.6E-08
Total	1.5E-01	7.3E-05	2.5E-04	1.5E-05	5.1E-14	9.6E-08

Table D.3.5–122. Intruder Scenario Risk Results for RH-LLMW (100 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	6.2E–03	3.1E–06	1.0E–05	6.2E–07	0.0	5.9E–13
INEL	13	6.4E–03	2.2E–02	1.3E–03	1.2E–14	8.8E–09
ORR	55	2.7E–02	9.3E–02	5.5E–03	0.0	2.3E–10
SRS	7.0E–02	3.5E–05	1.2E–04	7.0E–06	0.0	6.8E–11
Total	68	3.3E–02	1.2E–01	6.8E–03	1.2E–14	8.8E–09

Table D.3.5–123. Intruder Scenario Risk Results for RH-LLMW (300 years)

Site	Radionuclides				Chemicals	
	Dose (rem)	Cancer Fatality	Cancer Incidence	Genetic Effects	Cancer Incidence	Hazard Index
Hanford	4.7E–05	2.4E–08	8.1E–08	4.7E–09	0.0	5.9E–13
INEL	2.8E–01	1.4E–04	4.8E–04	2.8E–05	1.2E–14	8.8E–09
ORR	1.9	9.5E–04	3.2E–03	1.9E–04	0.0	2.3E–10
SRS	1.0E–03	5.2E–07	1.8E–06	1.0E–07	0.0	6.8E–11
Total	2.2	1.1E–03	3.7E–03	2.2E–04	1.2E–14	8.8E–09

D.3.5.9.1 *Results of the Human Health Risk Analysis for the Intruder*

For the Decentralized Alternative (which entails disposal at 15 sites), 100 years after the end of disposal operations, the site with the highest intruder cancer fatality risk is Hanford (9.4E–03) and the lowest cancer fatality risk is at FEMP (6.8E–07). The high dose at Hanford is due to large inventories of strontium–90 and cesium–137. Three hundred years after waste disposal is completed, the highest intruder cancer fatality risk is at INEL (1.2E–04), due primarily to a large inventory of nickel-63, and the lowest risk is at SNL–NM (8.2E–08).

For Regionalized Alternative 2 (involving disposal at six sites), 100 years following the end of disposal, the highest intruder cancer fatality risk is at Hanford (9.4E–03) due to strontium-90 and cesium-137; the lowest intruder risk is at NTS (7.1E–08). Three hundred years after disposal, the highest intruder cancer

fatality risk is at INEL (1.3E–04), where nickel-63 is the driving radionuclide; the lowest risk is at NTS (1.7E–08).

The Centralized Alternative (in which all waste is disposed at Hanford) poses an intruder cancer fatality risk of 3.6E–03 at 100 years, following the end of disposal activities. The controlling radionuclide is strontium-90. Three hundred years after disposal, the cancer fatality risk to the intruder decreases to 7.3E–05. The risks at Hanford under this single-site consolidation alternative are nearly three times lower than the risks at Hanford under the 15- or 6-site disposal options. While this may seem counterintuitive at first, it derives from the reduction in *average* waste concentration at Hanford that results when the waste volumes of low-activity wastes from other sites are added to the relatively higher-activity Hanford wastes.

For the RH-LLMW disposal scenario, 100 years after disposal operations cease, the highest cancer fatality risk is at ORR (2.7E–02) due to the presence of strontium-90 in the inventory. The lowest cancer fatality risk occurs at Hanford (3.1E–06). Three hundred years after the end of disposal operations, the highest intruder cancer fatality risk remains at ORR (9.5E–04), due to thorium-232, and the lowest risk remains at Hanford (2.4E–08). The driving radionuclide at ORR changes between the 100- and 300-year intrusions because strontium-90 decays through about 10 half-lives in the intervening 200 years whereas, thorium-232 has a half-life of approximately 14.1 billion years. As such, more than 99.99% of the material that was present at the close of disposal activities has decayed to lower-risk daughter products.

In general, the risks associated with intrusion at 300 years after closure of the disposal facility are less than those at 100 years due to the decay of radionuclides with time. The incidence of cancer associated with chemical exposures is eight to 12 eight orders of magnitude lower than the risk from exposure to radionuclides, and is well below levels of risk considered to be tolerable. The highest hazard index for any site is in the E–07 range, so exposure to noncarcinogenic chemicals is unlikely to lead to adverse health effects.

D.4 Uncertainty

The risks estimated in the preceding sections of the PEIS will be used to evaluate the alternatives based on cost, health risk, and environmental and socioeconomic impacts. These risks were calculated based on assumptions about the amount of contaminants released into the environment (source terms), the transport

of the contaminants through the air and groundwater to various populations, and the health effects to man resulting from the intake of these contaminants by inhalation or ingestion. These assumptions are necessary because the actual processes may be too complex to simulate or insufficient information is available to properly model the system. Because exact system definition is not possible, a *range* of possible values can be estimated; the most likely value (based on available data) is then chosen for calculating the risk. This range of possible values and the frequency with which these values occur are referred to as the "distribution." The model can be run using this distribution of input parameters to determine the range of risk estimates. This range is known as the risk uncertainty.

The risk uncertainty can be applied to the risk values given in the PEIS to get an estimated range of risks for each alternative. If part of the range of risks for one alternative overlaps the range for another alternative, it may not be possible to make a distinction between the two alternatives to determine which alternative poses the lower risk.

The standard method for determining risk uncertainties is quantitative, and involves estimating the range and distribution of each input parameter, producing a large number of input data sets that simulate those ranges and distributions, then running the model to determine the range of risks that result. However, the PEIS uses too many parameters and data sets for such an uncertainty analysis. Therefore, a qualitative uncertainty analysis was performed to assess the general accuracy of the PEIS risk estimates. This was done by performing an uncertainty analysis on a limited amount of data, then applying the results across all sites and alternatives.

As noted in previous sections, the uncertainties associated with risk analyses depend to a large degree on the various assumptions that are made when determining model methodologies, scenario definitions, and input parameters. Model uncertainties vary according to the model being used and how applicable that model is to the scenario; they are estimated during the verification and validation phase of model development. Usually, the model developers provide the model uncertainties and/or limitations of model applicability.

Scenario uncertainties include overlooking important receptors, not fully considering receptor activities (which could, for instance, lead to under- or overestimates of exposure), and so forth. Since the PEIS defines the scenarios to be analyzed for risk, these types of uncertainties do not apply in the alternative comparisons and, therefore, were not included in the uncertainty analysis.

Parameter uncertainties are caused by errors in measurements of the independent variables involved in the risk calculations and/or the representativeness of the samples taken for measurement. Since the PEIS is concerned with the comparison of *relative* risk estimates, only the parameters that cause a *relative* uncertainty between alternatives should be included. These parameters generally include all site-specific variables such as wind conditions or crop yields, as opposed to parameters that are common across all facilities, such as the breathing rate of humans and toxicity-related measures such as dose conversion factors.

The first step in this uncertainty analysis requires determining which parameters are significant, that is, which ones have the greatest influence on risk. Parameters that do not contribute to relative errors have been excluded from this uncertainty analysis, and are discussed in greater detail where appropriate in the following sections. The second step involves determining the uncertainty of each significant parameter. The third and final step is calculating the total risk uncertainty. Since different mathematical models are used for treatment and storage sites, disposal facilities, and waste management workers, the analysis will vary for each alternative. Uncertainties are presented in the following text, first for treatment and storage sites, then for disposal sites, and finally for waste management workers.

D.4.1 Treatment and Storage Sites

Atmospheric transport and subsequent inhalation, ingestion, and external exposure to contaminants were considered to be the only significant exposure pathways for treatment and storage sites (the groundwater and surface water transport pathways were excluded). To determine unit doses for the PEIS for radionuclides, the GENII code (Napier et al., 1988) was used. For hazardous chemicals, the ISC2 dispersion models (EPA, 1992a) were used. The risk uncertainty from using each of these codes had to be evaluated separately. To determine the general trends and magnitudes in risk uncertainty, a single, quantitative uncertainty analysis was performed using representative data from various sites. The results of this analysis are discussed according to their applicability across all sites.

To perform the uncertainty analysis for the PEIS, the measurement uncertainty and/or representativeness of the samples of all parameters having a significant influence on risk are needed. One significant variable is the source term. However, the uncertainties of the source terms for the PEIS were not provided by ANL at the time of this study and were, therefore, not included in this uncertainty analysis.

The uncertainties of other parameters, such as dose conversion factors, risk factors, and RfDs are associated with a high level of uncertainty. However, these parameters are determined apart from the PEIS and remain constant; therefore, any error associated with them is systematically applied across all facilities. In addition, although the health effects vary for each individual for a given exposure, the overall effects averaged across an entire population should be similar from one facility to another if that population is sufficiently large. Since the assumption that the populations were sufficiently large at all facilities was considered appropriate for a qualitative uncertainty analysis, the uncertainties from these parameters were not included in this study. The breathing rate of humans was also not considered in this analysis for similar reasons. Other parameters such as particle deposition velocity, resuspension parameters, stack flow rate, and stack exhaust gas temperature were assumed to be identical at all treatment and storage facilities since the facilities are not yet built and are hypothetical in nature. Therefore, these parameters were not included in this uncertainty analysis.

D.4.1.1 Radionuclides

To calculate the uncertainty associated with the estimated exposure caused by radionuclides, a sensitivity analysis of the GENII model was performed first, then the uncertainty analysis was made using only the significant parameters. The results are presented in the following subsections.

D.4.1.1.1 *Sensitivity Analysis of GENII*

A sensitivity analysis was performed to determine the variables that have a significant influence on the model's predictions of risk. Variables that were included in the sensitivity study included average air concentrations from a unit source for a specific area and population (called "Chi/Q"), agricultural yields, and what are termed "dietary fractions" (the rates at which a receptor consumes various nutrients such as water, grain, etc.). As noted in Section D.4.1, other variables such as breathing rates, particle deposition velocities, etc., were not included.

The GENII-S code (Leigh et al., 1992), developed by SNL-NM specifically for sensitivity and uncertainty analysis, was used to perform the sensitivity studies. The uncertainty associated with the annual effective dose equivalent (AEDE) due to the uncertainties associated with input parameters was determined. Latin

Hypercube sampling (Iman and Shortencarier, 1984) was used to generate a total of 300 input data sets that represent the distributions of the input variables. The results were subjected to regression analysis so that the statistically significant predictor variables could be determined. The regression equation simply fits a linear curve to the outputs from the Latin Hypercube samples:

$$Y = b + c_1x_1 + c_2x_2 + \ . \ . \ . \ + c_ix_i \qquad \text{(D.3-1)}$$

where Y is the predicted variable, b is the y intercept, x is the predictor variable, and c is the coefficient of the predictor variable in the linear formula. The null hypothesis that a coefficient was zero was tested to within the 95% confidence level; in other words, any coefficient that had a probability less than 0.05 of being zero was considered a significant parameter.

The parameters used in the sensitivity study included Chi/Q, 11 crop yields, and dietary fractions of cattle. To perform the sensitivity study, the range and distribution of each parameter had to be determined. To initialize input parameters, SRS was chosen as the site and a representative source term consisting of 1 Ci of each of the following radionuclides was used: tritium, carbon-14, phosphorus-32, sulfur-35, cobalt-60, strontium-90, yttrium-90, technetium-99, ruthenium-106, iodine-125, iodine-129, iodine-135, cesium-137, neptunium-237, thorium-229, uranium-238, americium-242, plutonium-238, and curium-245.

GENII–S uses Chi/Q as an input parameter. However, Chi/Q is actually a derived variable based on the joint frequency data, anemometer height, exhaust stack height, stack flow rate, stack diameter, and stack exhaust gas temperature; therefore, the uncertainty of Chi/Q had to be determined. Only the uncertainty in the site-specific joint frequency data was included in determining the uncertainty of Chi/Q, since the other parameters were not addressed (refer to Section D.4.1).

The joint frequency data for the 26 sites analyzed in the PEIS were collected from the MEPAS code (Droppo et al., 1989) (21 sites), the National Climatic Data Center (4 sites), and an environmental impact statement report (1 site). The joint frequency data comprise six wind speed ranges, seven stability classes per wind speed range (these stability classes indicate the number and intensity of wind gusts for a particular average wind speed range), and 16 wind directions (16 sectors of 22.5 degrees per sector; e.g., north, north-northeast, northeast, east-northeast, etc.). The uncertainties associated with each joint frequency data set are the measurement uncertainties for wind speed and direction and the representativeness of that data set relative to average wind conditions at the site over a specified period of time. The time period of interest

may differ for the release scenario. For a chronic release, the joint frequency data should represent wind speeds and directions averaged over the longest possible time period since the exposure period used in the human health risk analysis is equivalent to the average life span of an individual. However, for acute releases, such as would result from accidents, the data should be representative of a 1-year release since a 1-year constant release was assumed for acute release scenarios. The uncertainty of the joint frequency data is therefore a function of the variability of the wind on an annual basis and of how many years of data were used to estimate the average annual wind conditions.

To estimate the uncertainty in Chi/Q caused by the variations in atmospheric conditions, one site was chosen for which sufficient wind profile data were available to perform the analysis. (However, for a more complete uncertainty analysis, every site would have to be analyzed individually since the method for obtaining the data, the instrumentation used, the location of the meteorological tower relative to the facility, and the number of samples taken vary from site to site.) The meteorological data at the ORNL–East Tower were used since the data are readily available, fairly extensive, and measurement uncertainties are negligibly small compared to wind condition variability. The meteorological data are taken each hour, with measurement uncertainties of one degree for wind directions and 0.1 mph for wind speeds. Since GENII uses 16 wind directions of 22.5 degrees per directional sector, a 1-degree uncertainty in wind direction would have a negligible effect on the wind velocity profiles used for modeling (these profiles present wind velocity as a function of direction, by degree). GENII also uses only six wind speed ranges separated by approximately 2 mph and only seven stability classes. Therefore, wind speed uncertainties of 0.1 mph are negligible relative to model input capabilities for both mean wind speeds and stability classes.

The only uncertainty that must be considered is the representativeness of the joint frequency data to the "actual" conditions one would experience during exposure. To estimate this uncertainty for one site, the hourly data taken at the ORNL–East Tower were averaged over 1 year to produce one joint frequency data set for that year. Since data have been acquired since 1987, seven yearly data sets could then be constructed (1987–1993). The GENII code was run for each of these joint frequency data sets to determine a Chi/Q with all other parameters being constant. The results presented in Table D.4–1 show that the standard deviation for Chi/Q for this set of data is 1.27E–12. Two standard deviations are typically used to bound data within the 95% confidence level. Using two standard deviations, the uncertainty of the resultant Chi/Q is approximately $\pm 10\%$. Therefore, the joint frequency data averaged over 7 years would also be expected to have an uncertainty of no more than $\pm 10\%$.

Shor et al. (1982) (the source of the agricultural yield data) report that the margin of error for the agricultural yields is ±10%; the distribution had to be determined from the data in that study. From evaluating various yields from counties surrounding SRS, it was determined that a normal distribution was appropriate for the crop yields.

After the range and distribution of the input parameters were established, 300 input data sets were developed using the Latin Hypercube sampling technique. The regression analysis was then performed on the 300 model outputs. The coefficients resulting from the regression analysis and the probability of a coefficient being zero from the test of the null hypothesis are presented in Table D.4-2.

Table D.4-1. Descriptive Statistics for Chi/Q From ORR Meteorological Data

Statistic	Value
Mean	2.34E-11
Standard deviation	1.27E-12
Two standard deviations	2.54E-12 (10% of mean value)

Table D.4-2. Results of GENII Sensitivity Study

Variable	Coefficient	Probability
Chi/Q	113,787.87	0.000
Yield rate—Grain for human consumption	326.36	0.00
Yield rate—Fresh forage for beef cattle	202.11	0.05
Beef dietary fraction for stored feed	100.51	0.17
Yield rate—Stored feed for milk cows	74.28	0.09
Yield rate—Stored feed for poultry	31.17	0.73
Yield rate—Root vegetables	27.57	0.62
Yield rate—Stored feed for beef cattle	25.37	0.56
Yield rate—Leafy vegetables	-6.58	0.68
Yield rate—Fruit	-18.43	0.45
Yield rate—Fresh forage for milk cows	-32.35	0.75
Milk dietary fraction for stored feed	-42.69	0.56
Yield rate—Stored feed for laying hens	-102.27	0.25

Of all the variables considered in the analysis, only Chi/Q, the yield of grain for human consumption, and the yield of fresh forage for beef cattle were below the 0.05 probability level of having a zero coefficient. This means that the AEDE was most sensitive to variations in these three variables. Latin Hypercube sampling and regression analysis were performed again using these three variables only. The resulting partial correlations (which indicate the strength of the linear dependence of a parameter and factor out the first-order correlations between input variables) are presented in Table D.4–3.

Table D.4–3 reveals that the most sensitive variable was Chi/Q with a correlation coefficient of 0.99. This means that the uncertainty in Chi/Q will probably affect the uncertainties in risk much more than the uncertainties in the other two parameters. This is similar to the results found in an uncertainty study by Lyon et al. (1992), in which the Chi/Q correlation coefficient was 0.95. Despite the small contributions from the other two variables (grain yield for humans and fresh forage yield for beef cattle), the uncertainty analysis was performed using all three variables to ensure the thoroughness of the analysis.

D.4.1.1.2 *Uncertainty Analysis*

The uncertainty analysis was performed using the GENII–S code again, along with the three parameters shown in Table D.4–3. The results presented in Table D.4–4 show that the deviations in AEDE were ±9%. This is nearly the same uncertainty as that of Chi/Q (which, the reader will recall from preceding discussion, was ±10%); this is as expected, since the correlation coefficient of Chi/Q is 0.99.

Table D.4–3. Correlation Coefficients for Significant Variables

Variable	Partial Correlation
Chi/Q	0.99
Yield rate—Grain for human consumption	0.17
Yield rate—Fresh foliage for beef cattle	0.12

D.4.1.2 Hazardous Chemicals

The ISC2 code (EPA, 1992a) was used in the PEIS to estimate atmospheric fate and transport of hazardous chemicals. ISC2 estimates unit air concentrations for each block in a circular grid comprising 16 directional sectors (e.g., north, north-northeast, northeast, east-northeast, etc.) at 10 radial distances out to 80 km (50 mi) from the point of release, similar to the Chi/Q calculation in GENII. Because of the simplicity of the approach in ISC2, the Chi/Q, cancer potency factors, and RfDs are the only parameters used in modeling, and all are sensitive parameters on risk. However, recall from Section D.4.1 that the uncertainties in cancer potency factors and RfDs were not considered applicable in the PEIS uncertainty analysis since only relative, not absolute, uncertainties were being sought. Therefore, Chi/Q was the only sensitive variable in the ISC2 model for the purposes of this uncertainty analysis. Since the calculation for Chi/Q in ISC2 is almost identical to that in GENII, the uncertainties in Chi/Q are $\pm 10\%$.

D.4.1.3 Conclusion for Treatment and Storage Sites

The relative uncertainty of risk for the PEIS for comparison purposes could not be determined since the uncertainties in source terms were not available for this analysis. For the parameters pertaining to ingestion or inhalation, including Chi/Q, crop yields, and dietary fractions of humans and animals, the only significant parameter was Chi/Q, which had an uncertainty of $\pm 10\%$.

Because the uncertainties for parameters other than the source term are relatively low, the overall risk uncertainties should be of approximately the same order of magnitude as the source term uncertainties determined by ANL.

Table D.4–4. Descriptive Statistics for AEDE From the Uncertainty Analysis

Statistic	Value
Mean	2.5E+04
Deviation (Max-Mean)	2.15E+03 (9% of mean value)

If the critically exposed population in the PEIS is relatively small, the uncertainties in the breathing rates of humans, dose conversion factors, risk factors, and RfDs become significant, and the uncertainties in risk increase accordingly.

D.4.2 DISPOSAL SITES

Groundwater transport was considered the only significant environmental transport pathway for disposal sites. Three computer codes were used to estimate disposal risks. The DUST code (Sullivan, 1992) was used to estimate the amount leached from the disposal site; MEPAS (Droppo et al., 1989) was used to calculate fate and transport of the contaminants; and the DITTY portion of the GENII code (Napier et al., 1988) was used for the ingestion and exposure assessment. The uncertainty in these disposal risk calculations was estimated based on a sensitivity and uncertainty analysis of the MEPAS code conducted in April 1992 by ORNL and PNL (Lyon et al., 1992).

The applicability of the sensitivity and uncertainty analysis of the MEPAS code to the PEIS was evaluated. The locations studied by Lyon et al. were chosen to encompass high-risk sites (sites for which population fatalities were estimated at greater than 1), medium-risk sites (where population fatalities were predicted to range between 1 and 0.0001), and low-risk sites (with population fatalities estimated at less than 0.0001). Of the six contaminated sites studied, four involved the groundwater pathway. These four were ORNL Waste Area Grouping 6, the Hanford Nonradioactive Dangerous Waste Landfill Site, LLNL Site 300 Landfill 6, and FEMP Operable Unit 1. Because these four sites are located at four sites that were included in the PEIS health risk analyses, the results from the 1992 study were considered applicable to the PEIS.

Before relating the results of the study by Lyon et al. to the PEIS results, two differences must be pointed out. First, the PEIS used the DUST model instead of MEPAS to input the rate of contaminant release from the disposal site; however, the methodology used in the PEIS was identical to that used in the MEPAS study by Lyon et al. Second, the risk estimates in the study by Lyon et al. (1992) were time-weighted such that health effects that occurred sooner were weighted more heavily than those occurring later; the PEIS risks were not time-weighted. However, the contaminants in the Lyon study—uranium-238, strontium-90, benzene, and trichloroethene—moved through the groundwater at relatively similar rates and relatively fast; therefore, time-weighting the results would have a negligible effect on the uncertainties. Moreover, these contaminants are some of the primary constituents in the PEIS source terms. Because of these factors, the

variations in risk estimates determined by Lyon et al. (1992) should provide a reasonable estimate of the uncertainties in the PEIS.

Latin Hypercube sampling was used to perform the sensitivity and uncertainty studies. The sensitivity analysis was performed by PNL, which used the time-weighted number of health effects as the dependent variable. The initial sensitivity rankings of the inputs were based on the partial correlation coefficients (indicating the strength of the linear dependence of the parameters). Typically, only three to six parameters showed sufficient sensitivity to be considered for the uncertainty analysis at the various sites. The null hypothesis that a coefficient was zero was tested to the 95% confidence level (i.e., parameters were considered sufficiently sensitive if there was a probability of 0.05 or less that a parameter's coefficient in the regression equation was zero).

Table D.4–5 presents the input parameters with significant correlation coefficients and the number of orders of magnitude difference between the 95th percentile upper and lower confidence levels. The significant parameters are listed in order of the highest to lowest correlation coefficients. The authors concluded that the most vital components of the risk characterization process are the initial concentrations of contaminants,contaminant inventories, and contaminant flux rates at the site. In many cases, the final risk estimate is directly proportional to these values. Uncertainties in the subsurface partitioning coefficient, K_d, were determined to be insignificant relative to these other components.

Table D.4–5 shows that the differences in population risk estimates between the upper and lower 95th-percentile confidence bands ranged from 0.2 to 12.2 orders of magnitude. Note that the uncertainty at Hanford was very high in relation to the other three sites (12 orders of magnitude compared to 0.2, 1.5, and 2.1). This was because of a large decrease in population risk from the lower 80th percentile to the lower 95th percentile, accounting for approximately 10 orders of magnitude of uncertainty; there is only a difference of 2.2 orders of magnitude of uncertainty between the upper 95th percentile to the lower 80th percentile. Excluding the lower 80th to 95th percentile of the uncertainty for Hanford from consideration (because this behavior appears to be unique to Hanford and is extremely uncharacteristic of the other sites), the most reasonable estimate of the uncertainty with respect to disposal risks in the PEIS would be between 1 and 2 orders of magnitude.

Table D.4-5. Uncertainties of Risk Predictions via the Groundwater Pathway

Site	Significant Parameters (from highest to lowest correlation coefficient)	Population Risk Orders of Magnitude Difference[a]
ORR—Waste Area Group 6	1) Contaminant inventory 2) Surface K_d 3) Subsurface K_d 4) Discharge rate of White Oak Lake into the Clinch River	1.5
Hanford—Nonradioactive dangerous waste landfill site	1) Thickness of saturated zone 2) Waste leaching rate 3) Transverse dispersivity in saturated zone 4) K_d in saturated zone 5) K_d in partially saturated zone 6) Population drinking contaminated groundwater	12
LLNL—Site 300 Landfill 6	1) Flux rate 2) Leaching rate 3) K_d in first partially saturated zone 4) K_d in second partially saturated zone 5) K_d in saturated zone 6) Population drinking contaminated groundwater	2.1
FEMP—Operable Unit 1	1) Contaminant inventory 2) Pore water velocity in saturated zone 3) K_d in first partially saturated zone 4) K_d in second partially saturated zone 5) K_d in saturated zone 6) Travel distance in saturated zone to receptor	0.2

[a] Orders of magnitude difference between the 95th percentile upper and lower confidence levels.

This uncertainty estimate does not take into account uncertainties in the waste inventories provided by ANL. If the uncertainties in the inventories are provided by ANL, the risk uncertainty estimated in the preceding paragraph can be adjusted accordingly.

D.4.2.1 Conclusion for Disposal Sites

The most reasonable estimate of the uncertainty in the risk predictions in the PEIS for the disposal sites was expected to be approximately one to two orders of magnitude, based on the study by Lyon et al. (1992).

If ANL provides source term uncertainties in the future, the uncertainties in risk in the PEIS can be adjusted accordingly.

D.4.3 WASTE MANAGEMENT WORKERS

The MicroShield code (Grove Engineering, Inc., 1992) was used to calculate external radiation exposure to waste management workers for the waste management portion of the PEIS. MicroShield is capable of performing sensitivity studies for the shield thickness, distance-from-source-to-shield, and distance-from-source-to-receptor parameters. Sensitivity studies on other parameters such as material density and source strength must be performed manually.

For the comparison of PEIS alternatives, only the parameters that cause relative error, not absolute error, are the ones desired in determining the risk uncertainties. Since the PEIS treatment facilities and operational equipment were hypothetical in nature and were all assumed to be identical for the various treatments required, many parameters could be excluded from this uncertainty study. These included the shielding material and thickness, and the distances of the shield and receptor from the source.

Uncertainties were introduced in the PEIS risk estimates from relating waste throughputs to source volumes (volumes of waste in treatment vessels) and unit dose methodologies. For the PEIS, the throughput of waste for each treatment module for each alternative was provided by ANL. Since MicroShield requires input of the source (or waste) volume rather than the waste throughput, regression equations were used to relate throughputs to treatment vessel volumes using known values for existing facilities, derived from facility data provided by Morrison Knudsen Corporation (1993, 1994). The treatment modules that have variable capacities included feed waste bins, shredders, evaporators, high pressure spray/blast booths, solidification units, aqueous tanks, neutralization tanks, ion exchange tanks, oxidation reactor tanks, incinerators, metal melters, thermal desorption units, mercury roasting kilns, metal deactivation units, lead melting tanks, soil washing tanks, sludge washing tanks, debris washing tanks, and polymer blending tanks. (The size of some modules, such as drum compactors, did not change since the drum sizes remain the same for various throughputs; only the number of drums changed.)

There were two sources of error in the worker exposure calculations. First, the known throughputs and volumes consisted of three or four sizes categorized as extra-small, small, medium, and large. Since only

three or four sizes existed to derive the regression equations for each treatment module, the maximum error of the three or four known values was used, regardless of throughput.

The second source of error resulted from using the unit dose methodology, in which the unit dose to a worker is calculated based on exposure to 1 m^3 of waste in a 1-m^3 container. Since the capacity of some of the treatment modules varied, the unit doses had to be scaled to reflect the doses for the correct waste volumes in these cases. To derive this relationship, MicroShield was executed for each of the variable-size modules for a range of waste volumes, and a regression equation was used to relate the dose from the various waste volumes to the unit dose.

To estimate the uncertainty in risk predictions from these two sources of error, an alternative was chosen in which the treatment train consisted of throughputs and treatment modules for which larger errors on the regression curves existed. The management of LLMW at INEL in Regionalized Alternative 3 was chosen. Since the throughput changed with each of the 57 treatment modules for this alternative, and the number of workers changed with throughput, the actual dose for each treatment module had to be determined. The total actual dose was then calculated in an EXCEL spreadsheet and compared to that in the PEIS, resulting in an approximate $\pm 6\%$ error.

The shielding materials used for the PEIS included air, concrete, iron, and water. Since the construction, operation, and maintenance of all the facilities were assumed to be identical because the facilities are hypothetical in nature, any variations in the densities of concrete, iron, or water that might occur would cause absolute errors in risk predictions but would not cause relative errors (the type of errors sought for comparison purposes). The only site-specific parameter that might cause relative error would be air density since it is a function of the altitude of the treatment site. Because the sea-level air density of 0.00122 g/cm^3 was used for all locations in the PEIS, the error would be the difference between the average density at a specific location and the density at sea level. The altitudes for the facility locations in the PEIS ranged from sea level to approximately 5,300 feet at RFETS in Golden, Colorado. Therefore, the corresponding air densities ranged from 0.00122 to 0.00127 g/cm^3. This variability would have little effect on the shielding properties of air, so its effect on risk estimates would be negligible.

D.4.3.1 Conclusion for Worker Risk

Variability in parameters such as shield thickness, the distance-from-source-to-shield, and distance-from-source-to-receptor would be the major source of absolute error in risk estimates. However, these parameters would not have contributed to *relative* error since they were hypothetical in nature and were assigned identical values at all facilities. Uncertainties in the source terms and waste throughputs are significant for alternative comparisons in the PEIS since they are site-specific parameters. However, as with the source terms for the treatment and storage sites and disposal sites, ANL had not provided the uncertainties in source terms for WM workers at the time of this study; therefore, uncertainties for worker risks could not be determined. Because the uncertainties for parameters, other than source term, that contribute to relative error are relatively low ($\pm 6\%$), the overall risk uncertainties should be approximately of the same order of magnitude as the source term uncertainties determined by ANL.

D.5 Models Used in the PEIS Human Health Risk Evaluation

The ORNL Center for Risk Management used a number of computer codes to generate the PEIS human health risk estimates; these included numerous in-house codes based on established outside models for application of the unit risk approach.

GENII (Generation II of the Hanford Environmental Radiation Dosimetry Software System) (Napier et al., 1988) was used to assess the exposures to the offsite and noninvolved populations resulting from atmospheric releases of radioactive contaminants during routine facility operations and accidents, and to assess the intruder's radiological exposure to contaminated soil.

GENII is the second generation of a model developed for DOE at PNL to incorporate internal dosimetry models recommended by the ICRP into Hanford's existing environmental pathway analysis models. GENII analyzes environmental contamination resulting from both acute and chronic radionuclide releases by calculating radiation doses to individuals or populations from inhalation, ingestion of contaminated food and water, and external exposure through soil, water, and air. The GENII codes were developed under a stringent quality assurance plan based on American National Standards Institute (ANSI) standard NQA-1 as implemented in the *PNL QA Manual* (PNL-MA-70). It includes the DITTY (Dose Integrated Over Ten

Thousand Years) code, which was used to calculate doses to the hypothetical farm family in the disposal scenarios as described below.

GENII has been used worldwide by several hundred users. Some noted applications include the Hanford Defense Waste EIS, Hanford's annual reports, the Hanford Safety Analysis, the Reactor Retirement EIS for PNL, and the ANL New Production Reactor Study. It has also been accepted by the State of Washington.

EPA's ISC2 (Industrial Source Complex Dispersion Models, Version 2) (EPA, 1992a) was used to model atmospheric exposure modeling to chemical contaminants for the offsite and noninvolved worker populations. The code was designed specifically to support the EPA's regulatory modeling programs, and has EPA approval.

The DUST (Disposal Unit Source Term), MEPAS (Multimedia Environmental Pollutant Assessment System), and DITTY models were used in series to estimate exposures to contaminated groundwater. DUST was used to calculate the flux of contaminants released and transported to the disposal facility boundary; these fluxes were then used as the input to MEPAS. The transport portion of MEPAS was used for the vadose and saturated zone plume migration calculations; the output concentrations from MEPAS were then used as input to DITTY. The DITTY code was then used for dose assessment calculations.

DUST was developed at Brookhaven National Laboratory (BNL) (Sullivan, 1992). This code models the release and transport of radionuclides through a shallow land disposal facility. DUST contains models to predict fluid flow, container degradation, waste form leaching, and radionuclide transport. DUST is useful for screening to determine which radionuclide is released at the highest rate, and for parameter sensitivity analysis. It has been extensively tested and verified, and the code predictions have been compared to known analytical solutions and to other code predictions; several verification tests are provided in the *Data Input Guide* (Sullivan, 1992). An important application of DUST was the modeling of field lysimeter release data collected at ORNL and ANL over a 7-year period.

MEPAS (Droppo et al., 1989) was originally developed in 1986 by PNL to assist the DOE Office of Environmental Safety and Health in prioritizing sites for remedial activities. This model is an objective, physics-based, PC-platform system that uses mathematical algorithms and a pathway analysis to evaluate the release of contaminants into the environment; the movement of these contaminants through and between

multiple environmental media; exposure to surrounding human populations via inhalation, ingestion, dermal contact, and external dose; and the human health effects due to exposure to both chemicals and radionuclides.

MEPAS has been the subject of numerous technical reviews and has been widely used. Applications include the identification and prioritization of areas of existing environmental problems and risk at DOE's defense production facilities, and the assessment of potential risks for a number of commercial clients, the Hanford Site Single-Shell Tank Waste Characterization Program, the Hanford grout studies of hazardous waste risks, and 20 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites.

DITTY was used in the PEIS analysis to calculate radiological doses to the hypothetical farm family. DITTY was developed to calculate long-term population exposures from waste disposal sites; the time frame for calculations in DITTY is 10,000 years, divided into 143 periods of 70 years each. DITTY calculates the lifetime cumulative dose equivalent for each time period and the EDE for the period of maximum dose.

The risks due to chemicals for the intruder scenario and the surface water deposition study were estimated using an upgraded version of the PRESTO–II risk assessment code (Fields et al., 1986). PRESTO–II was developed at ORNL to assist EPA in assessing the potential human health impacts from the disposal of LLW. PRESTO–II, originally written for a mainframe computer, was based on methodologies presented in the U.S. Nuclear Regulatory Commission *Reg. Guide 1.109* (NRC, 1977) for the release, transport, uptake, and human health risk assessment of radionuclides released from a shallow land burial trench. The PRESTO–II code was downloaded to a PC and augmented with a windows interface; this version of the code is called PRESTO–W (Fields and Melescue, in preparation). Further code development included adding the capability to simulate near-field scenarios where the contaminant concentrations of the environmental media are known at the receptor location. PRESTO–W was also upgraded to estimate human health risks from chemicals. The chemical database in MEPAS was incorporated into PRESTO–W for initializing chemical properties, cancer slope factors, and RfDs. The hazard index and cancer risks from chemicals were calculated in PRESTO–W using the methodologies presented in the EPA Superfund risk assessment guidelines (EPA, 1989a).

The MicroShield 4 computer code (Grove Engineering, Inc., 1992) was used for assessing external radiation exposure to waste management workers. MicroShield 4 was developed for designing shields and containers, assessing radiation exposure to people and materials, making source strength calculations based on radiation

measurements, and teaching shielding principles. This model uses a highly structured ANSI standard programming language with good numerical precision. Data for attenuation coefficients, buildup factors, and buildup factor coefficients are taken from information distributed by the Radiation Shielding Information Center and included in ANSI/ANS 6.4.3.

MicroShield is currently being used by 400 organizations worldwide. For example, MicroShield was used in assessments of the Chernobyl accident in the former Soviet Union (Grove Engineering, Inc., 1992) and of various commercial nuclear utilities. Numerous universities including Kansas State University, Pennsylvania State University, the Massachusetts Institute of Technology, the Georgia Institute of Technology, and Rensselaer Polytechnic Institute use MicroShield for teaching shielding principles.

INEXPLC is a QuickBASIC program designed by ORNL System Safety Engineering (Bloom, 1993). The code includes relatively simple models that simulate close-in (i.e., less than 50 m downwind from the source) atmospheric dispersion, explosive releases, and particle deposition. These models are based on exact solutions to the differential equation of a convection, turbulent-diffusion model for a point source and a semicircular, finite-area source. In this model, it is assumed that simple gas dispersion takes place with no effects from nearby structures (building wake effects or downwash). The INEXPLC code was used in the WM PEIS worker risk analysis to estimate outdoor air concentrations from accidental chemical releases.

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