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Environmental Assessment for Double Tracks Test Site

Nevada Test Site, Nye County, Nevada

U. S. Department Of Energy

DOE/EA-1136

ENVIRONMENTAL ASSESSMENT FOR DOUBLE TRACKS TEST SITE

MASTER

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List of Acronyms and Abbreviations

AEC	U.S. Atomic Energy Commission
AQCR	Air Quality Control Region
BLM	U.S. Bureau of Land Management
CFR	Code of Federal Regulations
CGTO	Consolidated Group of Tribes and Organizations
cm	centimeter
dBA	decibel (A-weighted scale)
DOE	U.S. Department of Energy
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation
EA	environmental assessment
FFACO	Federal Facility Agreement and Compliance Order
ft	foot
FY	Fiscal Year
gal	gallon
ha	hectare
in.	inch
km	kilometer
km^2	square kilometer
m	meter
m^3	cubic meter
mi	mile
mi^2	square mile
mph	mile per hour
m/s	meter per second
NAEG	Nevada Applied Ecology Group
NAFR	Nellis Air Force Range
NAS	National Academy of Sciences
NTS	Nevada Test Site
pCi/g	picocurie per gram
PPE	personal protective equipment
RWMS	Radioactive Waste Management Site

List of Acronyms and Abbreviations *(Continued)*

SAFER	Streamlined Approach for Environmental Restoration
TRU	transuranic
TTR	Tonopah Test Range
USAF	U.S. Air Force
yd^3	cubic yard
ℓ	liter

Executive Summary

The U.S. Department of Energy, Nevada Operations Office (DOE/NV), with appropriate approvals from the U.S. Air Force (USAF), proposes to conduct environmental restoration operations at the Double Tracks test site located on the Nellis Air Force Range (NAFR) in Nye County, Nevada. This environmental assessment (EA) evaluates the potential environmental consequences of four alternative actions for conducting the restoration operation and of the no action alternative. The EA also identifies mitigation measures, where appropriate, designed to protect natural and cultural resources and reduce impacts to human health and safety.

The environmental restoration operation at the Double Tracks test site would serve two primary objectives. First, the proposed work would evaluate the effectiveness of future restoration operations involving contamination over larger areas.. The project would implement remediation technology options and evaluate how these technologies could be applied to the larger areas of contaminated soils on the Nevada Test Site (NTS), the Tonopah Test Range (TTR), and the NAFR. Second, the remediation would provide for the the removal of plutonium contamination down to or below a predetermined level which would require cleanup of 1 hectare (ha) (2.5 acres), for the most likely case, or up to 3.0 ha (7.4 acres) of contaminated soil, for the upper bounding case.

The proposed action at the Double Tracks test site includes three different excavation options for the environmental restoration of approximately 1 ha (2.5 acres) of contaminated soil. One or more options may be used to excavate contaminated material as part of the proposed action. In addition, a decontamination/animal hide burial area associated with the Double Tracks test would be located and excavated, and the contaminated material would be removed and disposed of properly. The proposed restoration operation would consist of constructing a staging area, excavating contaminated soil, transporting the soil and the contents of the burial area to an approved facility on the NTS for disposal, and stabilizing the soil and revegetating the remediated site. In addition, a well may be drilled to supply nonpotable water for construction activities. A revegetation study is under way near the project site. Depending on the results of this study, revegetation could consist of reseeding, reseeding with supplementary irrigation, or natural revegetation. The contaminated material would be transported from the work site to the NTS via private roads on the TTR and NTS and public roadways, including Nevada State Route 504 and U.S. Highways 6 and 95. The contaminated material would be disposed of at one of the existing low-level radioactive waste management sites in Area 3 or 5 of the NTS.

In addition to the proposed action, this EA evaluates the potential environmental impacts associated with three alternatives and a no action alternative. All of the alternatives, except the no action alternative, explore the same cleanup technologies as the proposed action. Differences between the alternatives involve timing and routing to the disposal sites. Potential transportation routes are identified for each alternative and include transport across the NAFR, with construction of new roadways; transport southwest across the NAFR to Lida Junction, then along U.S. Highway 95; and transport to the TTR for interim storage.

Impact evaluation for this EA focuses primarily on human health effects for transportation and remediation activities. Results of the human health effects analysis for the remediation activities indicate that the greatest risk is posed to workers by the industrial aspects of the project. The analysis was bounding (worst case) and determined that the remediation portion of the project would result in 0.0001 fatalities and 0.07 injuries due to excavation and handling activities if the cleanup level were 100 picocuries per gram (pCi/g). The remediation would also require workers to work in an environment where radiation hazards are present. Radiation exposure from remediation activities to the 100-pCi/g level would result in 0.00001 latent cancer fatalities and 0.000005 instances of adverse health effects that do not lead to cancer (i.e. radiation detriment). These risks would be reduced by approximately 50 percent using a cleanup level of 200 pCi/g. Impacts to the general public because of remediation activities could occur only through migration of the plutonium via air transport or transport to groundwater. Air transport modeling predicted the annual dose rate would be greatest to the public in the town of Goldfield of 0.006 millirem for the no action alternative. This is well below the 1.0-millirem-per-year dosage that would trigger the requirement for monitoring and would result in an estimated 0.000000003 latent cancer fatalities and 0.0000000012 radiation detriments per year to Goldfield residents. Human health impacts to the public would be less for the proposed action and each of the alternatives due to the short duration of the project and watering for dust suppression. In addition, although transport of plutonium to groundwater is very unlikely because the evapotranspiration rate is higher than the percolation rate for this area, some net downward movement of water could occur under rare circumstances. For such a case, the average concentration of plutonium in interstitial water would be approximately 40 pCi of plutonium-239 per liter of water and would be substantially diluted if it were ever to reach groundwater. This is equivalent to an ingestion dose of approximately 1 millirem per year to a member of the public if this groundwater were the only source of water and is less than the dose rate established by the U.S. Environmental Protection Agency for community drinking water.

The transportation portion of the project was also analyzed for human health effects. The analysis was bounding (worst case) and determined the consequences to the public and the transport crew. The estimated number of public vehicle fatalities during the length of the project for the proposed action would be 0.018; 0.15 vehicle injuries are estimated. Radiation exposure would result in 0.000000018 latent cancer fatalities and 0.0000000088 radiation detriments. The expected dose would be 0.11 person-millirem to both the driver and the public. This dose falls well below the total annual dose of 100 millirem allowable to individual members of the public.

New characterization data indicate that the actual area to be remediated likely will be approximately 1 ha (2.5 acres). Because characterization activities are still ongoing and the contamination area has not yet been finalized, no change will be made to the risk analysis. The bounding scenario will remain the same and provide risk data based on the remediation of 3 ha (7.4 acres) for the 200 pCi/g cleanup level.

The EA also identifies and discusses several resource areas that were determined to be unaffected (geology, surface water, wildlife, noise, historical and cultural resources, and socioeconomics). It was determined that other resources would bear only minor impacts (soils, microclimate, groundwater, air quality, vegetation, wild horses, aesthetics, and land use).

1.0 Purpose and Need for Action

1.1 Background

The U.S. Atomic Energy Commission (AEC) (now the U.S. Department of Energy [DOE]), in testing the safety of nuclear weapons under accident conditions, detonated single plutonium-bearing devices in such a fashion as to simulate an accidental detonation of the high-explosive portion of nuclear weapons. This resulted in the uncontained spread of plutonium and other radionuclides, such as americium and depleted uranium, in the environment in the vicinity of these experiments. Preliminary characterization data do not indicate the presence of regulated hazardous waste constituents. A total soil surface area of approximately 1,310 hectares (ha) (3,240 acres) throughout the Nevada Test Site (NTS), the Tonopah Test Range (TTR), and the Nellis Air Force Range (NAFR) was thus contaminated in excess of 200 picocuries per gram (pCi/g) (DOE, 1995a).

The Double Tracks site is located in Stonewall Flat on Range 71 North of the NAFR, northwest of the NTS (Figure 1-1). The nearest town is Goldfield, Nevada, located approximately 22 kilometers (km) (14 miles [mi]) west of the site.

Double Tracks was one of four experiments that constituted Operation Roller Coaster. On May 15, 1963, a device composed of plutonium and depleted uranium was demolished on a 2.4- by 2.4-meter (m) (8- by 8-foot [ft]) steel plate using chemical explosives (Church, 1969; Shreve and Thomas, 1965). No fission yield was detected; the total amount of plutonium deposited on the surface was between 980 and 1,600 grams (2.2 and 3.5 pounds) (Shreve and Thomas, 1965). In addition, small amounts of americium and depleted uranium were spread around the test site. The objectives of the Double Tracks test were to evaluate the dispersal of radionuclides and assess the short-term uptake and fate of plutonium in several animal species. The detonation scattered plutonium, americium, depleted uranium, earth, concrete, and metal into the air. The debris and most of the dirt fell to earth at relatively short distances; however, some of the material was spread over larger areas downwind, south of ground zero. Contaminated concrete and metal were subsequently collected and buried in a mound at ground zero. The contaminated surface around ground zero was scraped to a depth of several inches and placed in a pit or mounded, covered with soil, compacted, and watered (Talmage and Chilton, 1987). Debris and fragments that scattered to a radius of 450 m (1,500 ft) were also collected and placed in the pit (AEC, 1964). Postevent sampling and surveying of surface soil were conducted to determine contamination levels and distribution.

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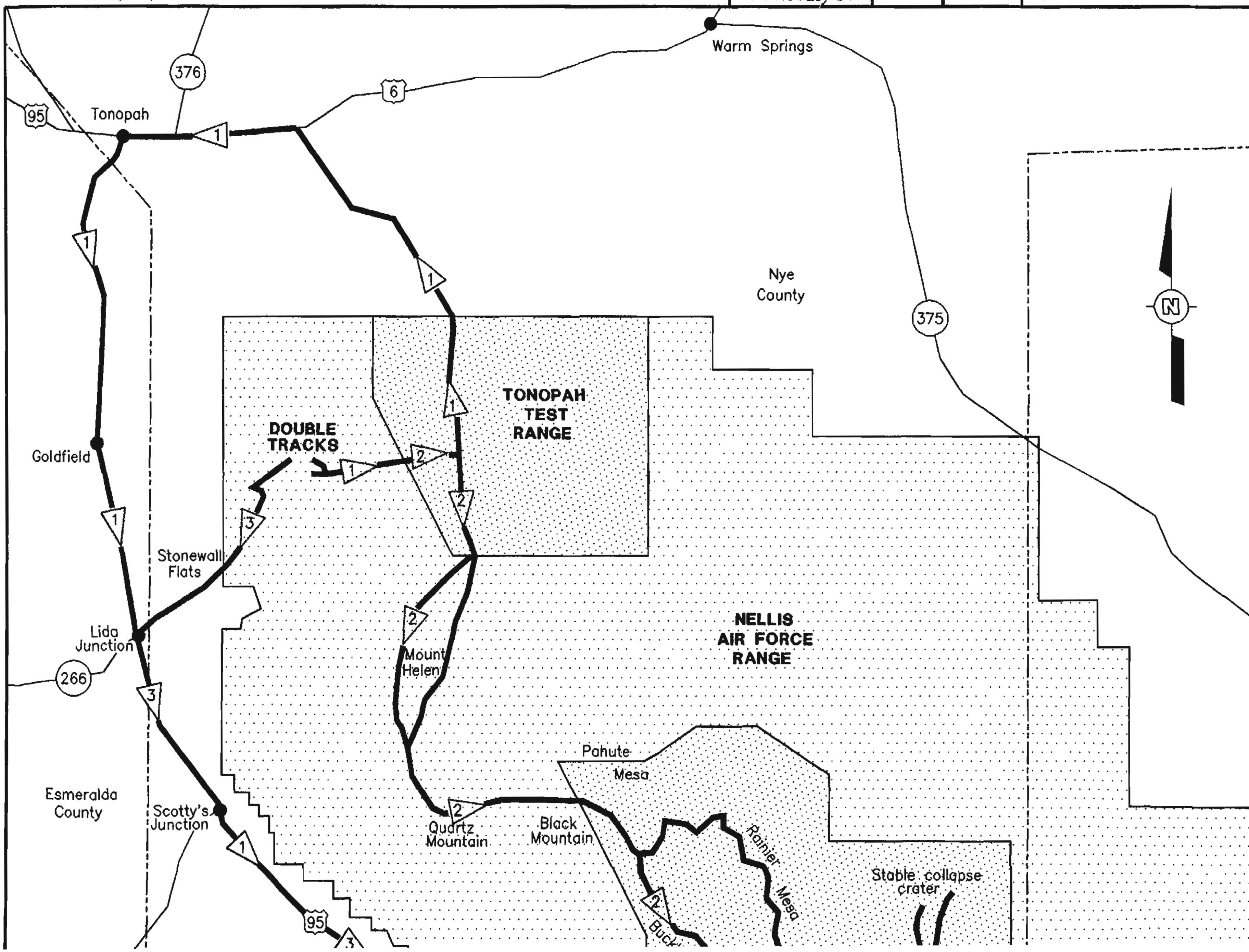

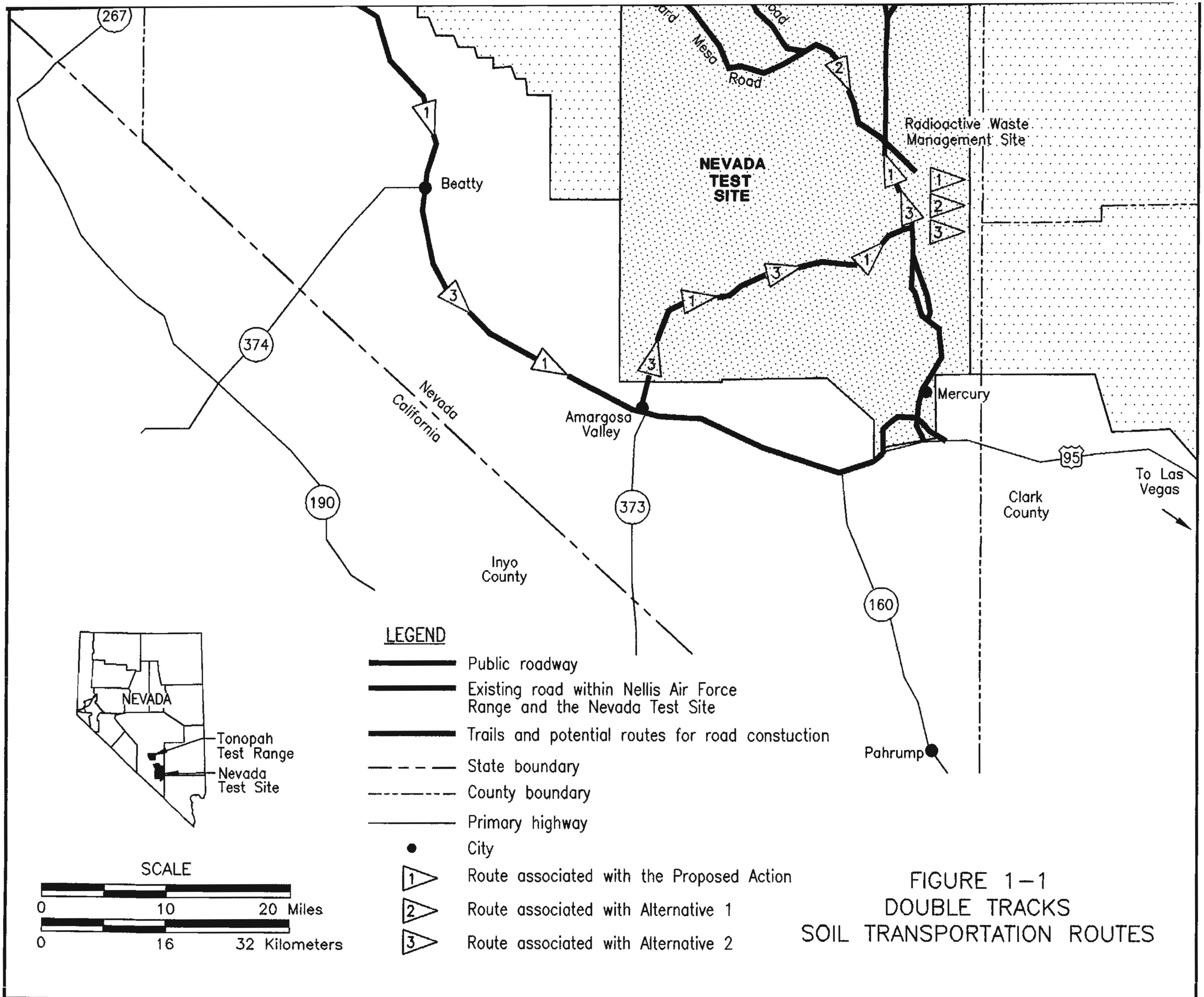

FIGURE 1-1
DOUBLE TRACKS
SOIL TRANSPORTATION ROUTES

During preliminary characterization work at the site, very highly radioactively contaminated metal fragments were found. These were placed in a drum and left at the site. More of these fragments will likely be found during further characterization.

To evaluate the uptake and fate of plutonium in animals, 84 dogs, 84 burros, and 132 sheep were placed at various distances from ground zero and covered with muslin shrouds to minimize external contamination (Wilson and Terry, 1965). Following detonation of the chemical explosive and the debris fall, the exposed animals were recovered and decontaminated. Of the 300 animals exposed, 18 were immediately sacrificed and autopsied. Radiation measurements taken immediately after the experiment confirmed the presence of plutonium on the shrouds that covered the animals during the experiment. The shrouds, decontaminants, and the hides of the animals that were sacrificed immediately following the test were buried at an unknown location. Although the exact location of the burial site is not known, several sites have been identified as potential locations. Based on remote sensing analysis for disturbed areas, field reconnaissance, interviews with test participants and limited geophysics, several potential areas have been identified. Several of these locations along Cactus Springs Road, west of the gate separating TTR and NAFR.

1.2 Purpose and Need for Action

In addition to Federal and applicable State requirements requiring cleanup of contaminated sites, DOE policy as stated in DOE Orders and the strategic plans of various DOE organizations is to ensure that risks to the environment and to human health and safety are either eliminated or reduced to prescribed acceptable levels. The DOE, the Defense Nuclear Agency, and the State of Nevada are presently negotiating a Federal Facility Agreement and Compliance Order (FFACO). This agreement is intended to outline the means by which sites of potential historic contamination are identified and proposed corrective actions based on public health and environmental considerations are arrived at and implemented. It is intended to "ensure that hazardous substances. . . which have been. . . released to the environment. . . are subject to corrective actions and closure requirements, under the oversight of NDEP."

The technical strategy for plutonium-contaminated soil sites, such as Double Tracks, will be based on either the Streamlined Approach for Environmental Restoration[1] (SAFER) or the

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[1]The Streamlined Approach for Environmental Restoration (SAFER) recognizes and manages the uncertainty in site remediation by combining established cleanup processes in a way that is faster and less costly than traditional approaches.

FFACO complex corrective action process. Surface soil remedies are proposed to include in situ identification and removal of hot spot materials in small selected areas. Larger areas would require the use of mechanical excavation to remove contaminated materials. Size separators or other physical processes would be used to reduce waste volumes along with mechanical excavation.

In support of the enforceable deadlines that will be established in the soon-to-be-approved agreement, technologies for remediating those plutonium-contaminated sites that require corrective actions need to be evaluated, developed, and improved. Technically viable and cost-effective excavation, transportation, and disposal methods need to be demonstrated while removing contaminated soils and all soils containing transuranic contamination exceeding 200 pCi/g. This level is conservatively estimated to be within the final cleanup level expected to be established in the future.

Given the uncertainties about what the full characterization findings will be, as well as the large size of the other sites, trial activities need to be conducted on a site of readily manageable size, contamination level, and extent. Administrative, technical, and logistical challenges must be relatively benign. The purpose of the Agency is to demonstrate and evaluate technologies for excavating contaminated soil while protecting human health and the environment. The Double Tracks site was selected because it is the smallest of the plutonium-contaminated sites, it is the closest to off-site receptors, and the extent of contamination at the site is readily manageable. The site location and existing conditions are expected to present relatively benign administrative, technical, and logistical challenges. Once the initial trials have been completed, the appropriate technology can be scaled to support any needed corrective actions at the larger sites.

Both the recovered and unrecovered highly radioactively contaminated metal fragments at the site need to be removed. In addition, the animal hides and shrouds burial site needs to be located and the contents properly disposed of.

1.3 Decision to be Made

The decision to be made is whether to implement the proposed action or to select one of the four other alternatives. The proposed actions and each of the alternatives are discussed in Section 2.0.

1.4 Environmental Issues and Scope of Analysis

An internal team determined the scope of the analysis through data collection and review of existing studies, reports, surveys, and plans; cultural resource information; and existing land use data and conditions. Through this process, it was determined that the proposed action and alternatives warrant impact analysis for the following areas of concern: soils, microclimate, groundwater, certain biological resources, aesthetics, land use, air quality, transportation, and human health risk. Resource areas that would not be affected or that would have minor or beneficial impacts from the proposed action and alternative actions are also discussed and include geology, surface water, wildlife, noise considerations, historical and cultural resources, and socioeconomic considerations.

2.0 Description of the Proposed Action and Alternatives

This section describes the proposed action and four alternatives, including the no action alternative. The proposed action and Alternatives 1 and 2 differ only with respect to the transportation route used. Transportation of contaminated materials would be through the Cactus Range and the TTR road network, followed by use of public highways to the NTS for the proposed action; through the NAFR to the NTS for Alternative 1; and southwest across the NAFR to Lida Junction, then along public highways to the NTS, for Alternative 2. Alternative 3 could include the same transportation route as for the proposed action or for Alternative 1; however, the contaminated material initially would be transported to the TTR for interim storage. Alternative 4 is the no action alternative.

For Alternatives 1, 2, and 3, site preparation, excavation, disposal, soil stabilization and revegetation, and pertinent assumptions are the same as for the proposed action unless otherwise noted. The proposed action would provide for the cleanup of 1 ha (2.5 acres) of contaminated soils, for the most likely case, or up to 3.0 ha (7.4 acres) of contaminated soil, for the upper-bound case. The proposed action would also serve to demonstrate and evaluate technologies for excavating contaminated soil while controlling dust. Based on the results of the evaluations, the appropriate technology or technologies could be scaled for application to the much larger areas of plutonium-contaminated soils. The scope of the excavation activities at the animal hide burial area will depend on whether the burial area is successfully located using historical data in order to limit ground disturbance and minimize costs. A remote-sensing analysis has been conducted to identify areas of disturbance that may indicate the location of the hide burial site. Interviews were also conducted with personnel involved with the test. Based on this work, it appears that the burial site may be located in the flat below the Cactus Springs Ranch.

2.1 Proposed Action

The proposed action is a voluntary corrective action that includes establishment of a staging area for on-site project administration, operations, maintenance, and decontamination; excavation of soil contaminated in excess of 200 pCi/g; transport of excavated soil through the TTR and on public highways to the NTS; disposal at the NTS; and soil stabilization.

The proposed action would involve clearing an area of 1 ha (2.5 acres) for a staging area, remediating a contaminated area of 3 ha (7.4 acres), disturbing an area of up to 0.10 ha (0.25 acres) to search for and excavate the hide burial site, and using an area up to 1 ha

(2.5 acres) for a well or sump. The impact analysis is based on this total (bounding) area of disturbance. The five components of the project (staging site preparation, excavation, transportation, disposal, and soil stabilization) are described in the following paragraphs.

Staging Site Preparation

Site preparations will be required prior to the start of work. The U.S. Air Force (USAF) would schedule flight paths away from the work site during work hours. An area of about 1 ha (2.5 acres) would be cleared of vegetation for administrative trailers, maintenance facilities, and a decontamination area. Water for dust control, decontamination, and irrigation would either be hauled by truck from the TTR to a sump or be obtained from a well drilled near the site. If a well is drilled, it is expected to provide about 750 liters (ℓ) per minute (200 gallons per minute) of water from a depth of 180 m (600 feet). Water from this well would be used for nonpotable purposes, primarily for dust suppression, decontamination, and irrigation during the expected project duration of 60 ± 30 days. Water requirements are expected to reach a maximum of 757,000 ℓ (200,000 gallons [gal]) per day on an intermittent basis. A water storage tank, with an approximate capacity of 757,000 ℓ (200,000 gal), would also be provided within this area. Upon completion of this project, the well and water tank would be retained by the USAF for use in range maintenance and construction, at USAF discretion. In addition, the Cactus Springs Road would require grading and compaction for use by trucks delivering support equipment and subsequently transporting soil from the project area to the disposal site at the NTS. Prior to the start of operations, generators would be brought to the site to supply power for administrative trailers and facilities.

Excavation

The excavation component consists of the use of four options: (1) a front-end loader, (2) a self-loading scraper to excavate and collect soil, (3) a pavement profiler (rotomill) to excavate the soil and load it onto a transfer vehicle, and (4) a motor grader to windrow a thin cutting of soil and a scraper to remove the windrows. The actual excavation may be performed using a combination of these options. The excavation equipment would remain in the exclusion zone for the duration of the excavation, unless repair work dictates decontamination and removal. Excavation would start in May 1996, with an expected duration of 60 ± 30 days.

Soil would be stockpiled at a location on the edge of the contaminated area in the contamination reduction zone. Beginning in June 1996, the soil would be transferred from the stockpile to double-lined plastic bags designed to hold 900 kg (1 ton) of soil. The bags, also known as "super sacks," would then be loaded into closed trucks for transport. Alternatively, the soil may be passed through a soil screening device, such as a grizzly, and into an auger conveyer, which would load the soil directly into the super sacks for transport. Vehicles would be configured to preclude spillage through a closed trailer design and by containerizing the load in the super sacks.

In addition, the Double Tracks decontamination/animal hide burial area would be excavated after verification of its location. Although the dimensions of the burial site are not known, historical data and interviews with Double Tracks operation workers indicated that the area may be about 3 m (10 ft) deep, 9 m (30 ft) long, and 2 m (7 ft) wide. An approximate 30- by 30-m (100- by 100-ft) area would be cleared for excavation purposes.

Preliminary characterization has indicated that some of the contamination consists of small, discrete chunks of contaminated metal or slag-like material rather than finely dispersed particles. Field readings indicate that these discrete elements exhibit concentrated radioactivity and may qualify as transuranic (TRU) waste when further analyzed. TRU waste is defined as waste that has transuranic elements (i.e., has an atomic number greater than 92, is an alpha-emitter, and has a half-life greater than 20 years) and has an activity higher than 100 nanocuries per gram. These "hot spots" would be located during remediation and gathered for separate storage and disposal. The total volume of hot spot material is not expected to exceed 0.50 m^3 (0.65 yd^3).

Although no remediation level has been determined, assuming for analytical purposes, a cleanup level of 200 pCi/g, the proposed action would involve the removal of approximately 1,240 cubic meters (m^3) (1,620 cubic yards [yd^3]) of soil contaminated with transuranics. The level of contamination of the bulk soil removed would not qualify it as TRU waste. This volume does not account for the expansion of soil when disturbed by excavation, which is expected to contribute an additional 20 to 50 percent (volume) at the Double Tracks site.

Support activities occurring concurrently with the soil removal action would include vehicle decontamination, dust suppression by application of water and possible chemical stabilizers, road maintenance, and air monitoring for health and safety purposes. During excavation work in the contaminated zone, personal air monitors would be worn by workers in compliance with the health and safety plan in effect at that time and work would be conducted in accordance with OSHA and DOE Orders. In addition, a minimum of three air monitoring stations would be established on the perimeter of the site to monitor dust generation.

Transportation

Making one round-trip per work shift, trucks would travel, individually or in convoys, approximately 450 km (280 mi) from the site to the disposal facility at the NTS. Routing would be east across the Cactus Range to the TTR, north from the TTR on Sandia Drive (State Route 504) to the junction with U.S. Highway 6, west on U.S. Highway 6 to the intersection with U.S. Highway 95 in Tonopah, and south on U.S. Highway 95 to the NTS (Route 1 in Figure 1-1). Trucks could enter the NTS through the Lathrop Wells Road gate near the small community of Amargosa Valley or through the main gate near Mercury. Assuming that the effective capacity of each transport vehicle is 13 m^3 (17 yd^3), an estimated 95 ± 35 loads would be required to transport the soil. The expected duration of loading and transporting soil is 60 ± 30 days. Transuranic waste, if present, would be transported in accordance with applicable regulations for storage at the NTS TRU pad at the Area 5 Radioactive Waste Management Site (RWMS). In addition, approximately five fully loaded trucks would be needed to transport the contents of the animal hide burial area to the NTS for disposal. The trucks would be appropriately placarded, and all shipping would be conducted in compliance with U.S. Department of Transportation (DOT) regulations. Waste would be packaged or shipped in closed vehicles in accordance with applicable DOT regulations. In addition, truck drivers would be trained and made aware of potential hazards along the transportation route, including the slow speed required to negotiate the sharp turn near the south end of Goldfield. In preparation for waste transport, emergency services would be notified of the transportation routes and appropriate response procedures, and meetings would be held to make residents aware of the appropriate actions to minimize problems in the unlikely event of an emergency or spill.

Disposal

At the NTS, Double Tracks soil would be placed into operating landfills, either the Area 3 Bulk RWMS or the Area 5 RWMS. Using a worst case soil expansion factor of 50 percent for the Double Tracks soil results in a total waste volume of approximately 1,860 m^3 (2,430 yd^3) for disposal. This is not a sufficient volume to require closure of existing cells at the Area 3 Bulk RWMS or the Area 5 RWMS, as it represents only 1 to 3 percent of the remaining capacities and an increase of only 15 percent over the waste accepted annually at either facility. Approximate remaining capacities of the Area 3 Bulk RWMS and the Area 5 RWMS are 155,830 and 65,130 m^3 (203,820 and 85,186 yd^3), respectively. Transuranic waste, if produced, would be disposed of after the resolution of issues pertaining to disposal of the waste type.

Soil Stabilization

Upon completion of site remediation, the site would be treated with chemical soil stabilizers to ensure short-term stabilization. Long-term stabilization and restoration of the site would be accomplished by establishing a permanent plant community. Preference would be given to native species in order to minimize maintenance requirements.

2.2 Alternative 1

Staging site preparation, excavation, disposal, and soil stabilization methods would be the same as described for the proposed action (Section 2.1).

Transportation

Trucks would travel, individually or in convoys, approximately 260 km (161 mi) from the site to the disposal facility at the NTS through the NAFR Range on a combination of existing, rebuilt, and new roads. Construction of new roads across the NAFR Range would require the approval of the USAF. Loaded vehicles would travel across the Cactus Range to the TTR, then southward across the TTR and the NAFR. The route across the NAFR would require the construction of approximately 48 km (30 mi) of new roadway. The new road would follow existing jeep trails and/or traverse disturbed areas wherever possible to mitigate impacts. The route would cover approximately 80 km (50 mi) across the NAFR and would enter the NTS at Pahute Mesa in Area 20 (Route 2 in Figure 1-1). As with the proposed action, approximately five fully loaded trucks would be used to transport the contents of the animal hide burial area to the disposal site. TRU waste, if present, would be transported in accordance with applicable regulations for storage at the NTS TRU pad at the Area 5 RWMS. Waste would be packaged or shipped in closed vehicles in accordance with applicable DOT regulations.

2.3 Alternative 2

Staging site preparation, excavation, disposal, and soil stabilization methods would be the same as described for the proposed action (Section 2.1).

Transportation

Trucks would travel, individually or in convoys, approximately 32 km (20 mi) from the Double Tracks site southwest across Stonewall Flat on rebuilt and newly constructed roads to join U.S. Highway 95 near Lida Junction. The trucks would then follow U.S. Highway 95 to the NTS entrance at Lathrop Wells or the main gate near Mercury for final disposal on the NTS (Route 3 in Figure 1-1). The total transport distance along this route is approximately 310 km (192 mi) and would require construction of 29 km (18 mi) of new roadway on the NAFR. Road construction would require USAF approval. As with Alternative 1, use of existing jeep trails or other previously disturbed areas would be given preference over selection of new alignments through undisturbed areas. As with the proposed action, approximately five fully loaded trucks would be used to transport the contents of the animal hide burial area to the disposal site. Transuranic waste, if present, would be transported in accordance with applicable regulations for storage at the NTS TRU pad at the Area 5 RWMS. Waste would be packaged or shipped in closed vehicles in accordance with applicable DOT regulations.

2.4 Alternative 3

Staging site preparation, excavation, disposal, and soil stabilization methods would be the same as described for the proposed action (Section 2.1).

Transportation

Trucks would travel, individually or in convoys, approximately 38 km (24 mi) from the site to a temporary storage facility at the TTR. The soil would be bulk-shipped in trucks (with appropriate coverings) to an interim storage facility at the TTR complex (Figure 1-1). Each vehicle would make several round-trips per work shift to the TTR temporary storage site. Temporary storage at the TTR would be functional if a permanent disposal facility at the NTS dedicated to the disposal of plutonium-contaminated soils is determined to be desirable. Storage would continue until the necessary studies were completed. If a decision were made to construct such a facility, the soil would be transported to the NTS for permanent disposal once the facility was ready to accept the waste. The routing, loads, and duration to transport the soil from the TTR to the permanent disposal site at the NTS would be similar to that described for either the proposed action or Alternative 1. As with the proposed action, approximately five fully loaded trucks would be used to transport the contents of the animal hide burial area to the temporary site prior to final disposal. Transuranic waste, if present, would be transported in accordance with applicable regulations for storage at the NTS TRU pad at the Area 5 RWMS. Waste would be packaged or shipped in closed vehicles in accordance with DOT regulations.

2.5 Alternative 4: No Action Alternative

The no action alternative represents the existing site environmental conditions against which the impacts of the proposed action and alternatives are compared. Under the no action alternative, no remediation activity would be initiated. Because the existing site conditions and soil contamination would remain intact, continued security would restrict access.

3.0 Affected Environment

The Double Tracks site is located on an alluvial surface in Stonewall Flat. Stonewall Flat is bordered by the Cactus Range to the east, the Goldfield Hills to the northwest, and Stonewall Mountain to the south. The Double Tracks test site is relatively flat; surface runoff is toward the southwest. The elevation of the site is approximately 1,520 m (5,000 ft) above mean sea level. Vegetation is sparse, and desert pavement is present in areas where plants are absent. Blow-sand mounds occur beneath shrubbery. In bare areas, gravel constitutes an appreciable portion of the uppermost few centimeters of the soil (approximately 20 percent by weight); in desert mounds, the upper few centimeters of soil consists of more than 90 percent sand (Tamura, 1977).

Original estimates of areal distribution of plutonium activities at the Double Tracks site were developed using soil sample data generated by the Nevada Applied Ecology Group (NAEG) and EG&G aerial surveys. The NAEG soil sample data indicate that radionuclide concentrations in surface soil are highly variable over relatively small horizontal distances. Radionuclide contamination generally occurs within the top 2 to 5 centimeters (cm) (1 to 2 inches [in.]) of soil, although plutonium has been detected at greater depths (Essington et al., 1975). Recent in situ analyses being completed for inclusion in an upcoming characterization report indicate that the areas of contamination may be significantly overestimated. However, the NAEG and EG&G area estimates are used herein to indicate bounding conditions, even though the 1-ha (2.5-acre) area indicated as requiring remediation to achieve the 200-pCi/g level is considered the most likely case.

3.1 Geology and Soils

The site is located in the Great Basin geologic province. This region is characterized by interior drainage and north-south-trending fault blocks that were formed by Late Cretaceous to early Tertiary extension, with rock ranging in age from Precambrian to Tertiary. Quaternary rock formations dominate the Stonewall Flat/Double Tracks site area. Dominant soils can be classified as alluvium and gravel. This valley-fill material consists of alluvial fan, fluvial, fanglomerate, and lakebed deposits.

The soil in the project area was contaminated by the Double Tracks test. Contamination levels vary with distance from ground zero and as a function of wind direction at the time of the test. At the 200-pCi/g level and above, the areal extent of contamination is estimated to be approximately 1 ha (2.5 acres) as illustrated by Figure 3-1. Additional information on risk due to contamination is presented in Section 3.11.

3.2 Microclimate Conditions

The NAFR has a semiarid climate. Annual precipitation is low, approximately 15 cm (6 in.) per year (French, 1983). Precipitation in the project area is characterized by two maxima: the primary in the winter and the secondary in summer. Prevailing winds are normally from the southwest, with average wind velocities ranging from 4 to 5 meters per second (m/s) (9 to 11 miles per hour [mph]) in the morning and increasing to 5 to 6 m/s (11 to 13 mph) in the afternoon.

3.3 Water Quality

This section describes water quality in the site vicinity in terms of surface water and groundwater.

3.3.1 Surface Water

The project area contains no perennial surface waters. Ephemeral surface drainage north, west, and east of the Double Tracks site gathers in the Stonewall Flat playa, which borders the south edge of the project site. No floodplains or wetlands are present near the project area. Evaporation rates greatly exceed precipitation rates.

3.3.2 Groundwater

The greater precipitation in the mountains provides most of the recharge to the groundwater system; water that reaches the desert floor, such as at Stonewall Flat, is lost primarily through evaporation. Annual evaporation at the site is approximately 150 cm (59 in.) (French, 1983). Estimated depth to groundwater is 130 m (430 ft) in the project area. No wells are present in the near vicinity, thus, no water-quality information is available. The Stonewall Flat groundwater system is part of the groundwater system that discharges in Sarcobatus Flat, northwest of Beatty along U.S. Highway 95.

3.4 Biological Resources

This section describes the biological resources in the project area.

3.4.1 Vegetation

The project area is characterized by the saltbush shrub community, which typically is found primarily in valley bottoms and between elevations of 1,200 and 1,500 m (4,000 ft and 5,000 ft).

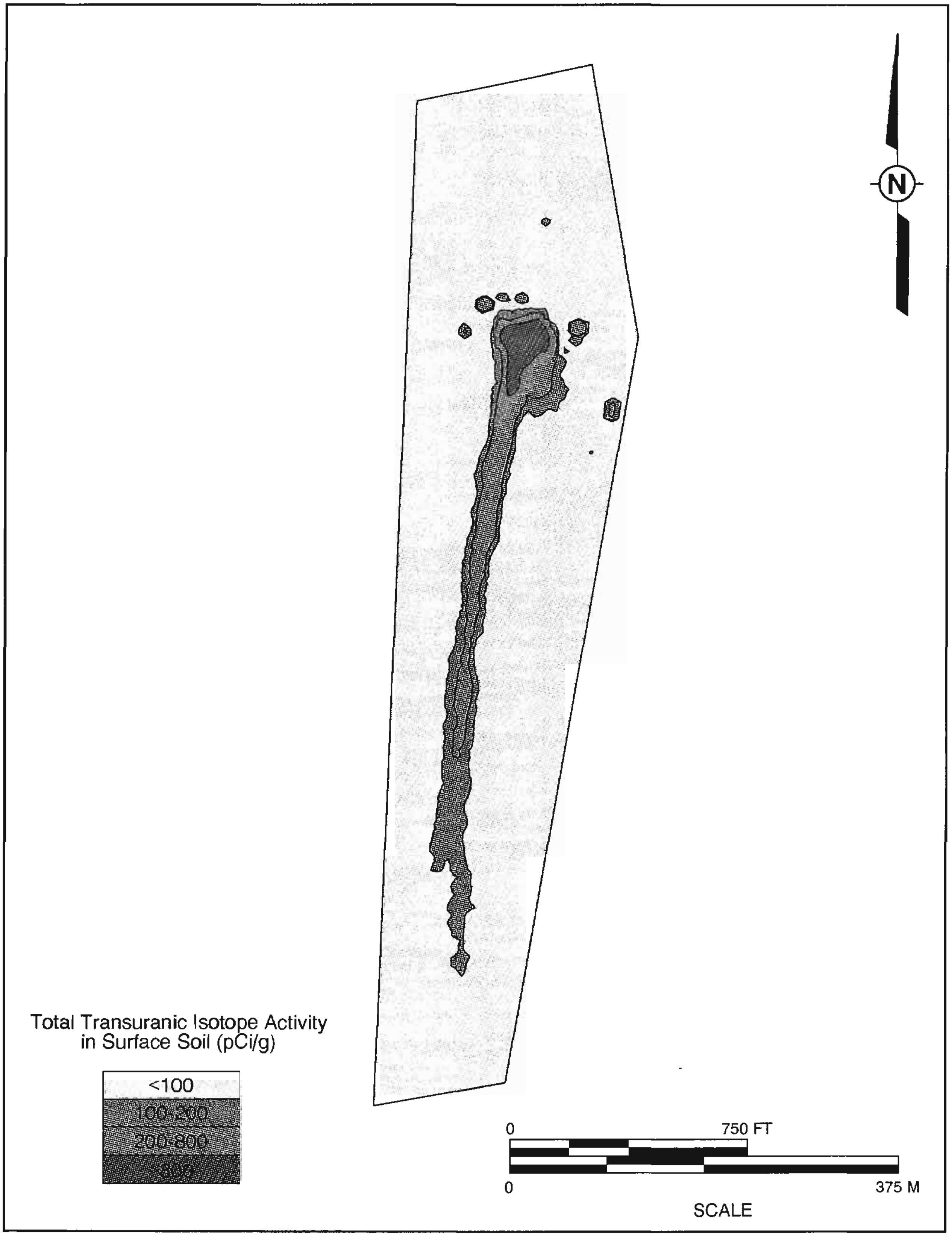

Figure 3-1

Total Transuranic Isotope Activity of Double Tracks Soil, Based on 1995 EG&G Ground Survey

The vegetation association is mixed desert shrub. Common shrub species are shadscale *(Atriplex confertifolia)*, greasewood *(Sarcobatus vermiculatus)*, budsage *(Artemisia spinescens)*, cheesebush *(Hymenoclea salsola)*, green ephedra *(Ephedra viridis)*, winterfat *(Ceratoides lanata)*, and seepweed *(Sueda fruticosa)*. Common grasses and forbs include Indian ricegrass *(Oryzopsis hymenoides)*, fluffgrass *(Erionuron pulchellum)*, and pepperweed *(Lepidium densiflorum)*. No federally listed threatened or endangered plant species are found in the project area.

3.4.2 Wildlife and Wild Horses

The project area is only sparsely inhabited by animal populations. The major forms of wildlife in the vicinity of the site include small mammals such as ground squirrels *(Ammospermo philus)*, kangaroo rats *(Dipodomys)*, and pocket mice *(Perognathus)* and lizards such as western whiptails *(Cnemidophorus tigris)* and side-blotch lizard *(Uta stansburiana)*. Larger mammals include jackrabbits *(Lepus californicus)*, desert kit fox *(Vulpes velox macrotix)*, coyotes *(Canis latrans)*, and badgers *(Taxidea taxus)*. Many of the larger mammals reside in the mountain ranges approximately 26 km (16 mi) southwest and 23 km (14 mi) northeast of the project area. Wild horses are the exception. The wild horse population lives mostly in the north-central and northwest portions of the NAFR, with major foraging use in the Kawich Valley, Cactus Flat/Gold Flat, Goldfield Hills, and Stonewall Mountain areas. Because of the seasonal availability of forage, the higher elevations receive heavier forage use during the summer months and the lower valleys receive heavier use during the winter. On occasion horses may venture into the Double Tracks area and become trapped in fencing or a cattle guard.

No federally listed threatened or endangered species are known to occur within the project area. State-listed species are also absent.

3.5 Air Quality

The Double Tracks site is entirely within the Nevada Intrastate Air Quality Control Region (AQCR 147) (U.S. Bureau of Land Management [BLM], 1990). The AQCR is designated as unclassifiable/attainment for all criteria pollutants. A regional air quality assessment was conducted in 1979 and indicated that the dispersion characteristics for the NAFR are good to fair and that the highest potential for exceeding air quality standards occurs in the valleys during the winter months of December, January, and February (BLM, 1990). In April 1995, an air sampling station was established in the vicinity of the Double Tracks site. The sole purpose of the station is to collect weekly or biweekly samples of particulate matter in the air directly west of the contaminated zone.

3.6 Noise Considerations

Because of the remoteness of the Double Tracks site, the access restrictions associated therewith, and the lack of nearby population, the public has little to no exposure to noise. Present conditions include only noise due to the intermittent USAF operations in the area. The USAF uses airspace above the project area for aircraft maneuvers and bombing approaches; however, to provide for worker protection, flight paths would be altered during the restoration activity.

3.7 Land Use and Aesthetics

The project area has remained unused since the Double Tracks test in 1963. Access to all of the NAFR is restricted, which precludes all public uses, including recreation. Authorized agricultural operations on the NAFR ended in 1959, when livestock grazing was discontinued. Stonewall Mountain has the best potential recreational opportunity in the general project area and could provide hunting and spring oriented activities if access were available.

The Double Tracks project area cannot be seen from a public area or thoroughfare. The site lies in a gently sloping area of low scattered brush and presents little visual interest. Surface disturbance in the area has been limited to fencing, arcs centered on ground zero, access roads, and vehicle tracks to the ground zero area. Surface damage due to testing activities has become less noticeable over the years.

3.8 Historical and Cultural Resources

As a Federal agency, the DOE is responsible for compliance with the National Historic Preservation Act of 1966, as amended. Section 106 of the Act, *Preservation of Historic Properties*, and its implementing regulation (Title 36, Code of Federal Regulations [CFR], Part 800) require agencies to perform three phases of work before an undertaking is conducted. Phase 1 consists of the identification of any cultural resources located within the area of potential effects of the undertaking. Phase 2 includes the evaluation of identified cultural resources for eligibility for the National Register of Historic Places. During this phase, potential effects to eligible resources are also assessed. If the analysis determines that the undertaking would affect eligible resources, then Phase 3 mitigation must be conducted.

Because of the nature and extent of contamination known to be present in portions of the project area, no complete cultural resources inventory has been conducted. To date, information on cultural resources in the project area and its environs is provided in two reports by the Desert Research Institute (King and Johnson, 1994; Johnson, 1995). The first is a historical evaluation of the Double Tracks test site which found the site to be historically important, but not eligible for the National Register of Historic Places. The other indicates that approximately 272 ha (670 acres) within the remediation area (exclusive of the fenced portion of the contaminated zone) were surveyed and identifies seven isolated prehistoric artifacts and one prehistoric site. None of these are eligible for the National Register of Historic Places.

The amount of cultural material recorded on the surface in areas adjacent to the project area suggests a low but extant sensitivity for these resources. Buried resources may also exist. However, the potential for intact buried deposits within the Double Tracks fenced contamination area is low given the surface disturbance due to site preparation prior to the detonation of the explosive device and subsequent scraping and piling of debris into a central mound.

3.9 Socioeconomics

The Double Tracks site is located on the NAFR. The majority of the transportation routes are located on the NAFR and on the NTS, and the disposal facilities are on the NTS. The closest population center is the unincorporated town of Goldfield, approximately 22 km (14 mi) west of the site in Esmeralda County. U.S. Route 95, which is a proposed transportation route for contaminated soil from Double Tracks to the NTS, passes through the communities of Tonopah, Goldfield, Beatty, and Amargosa Valley. Except for Goldfield, all of these communities, as well as the NAFR and the NTS, are located in Nye County. Figure 3-2 details the region of influence for the Double Tracks restoration operations.

Nye County covers approximately 46,786 square kilometers (km^2) (18,064 square miles [mi^2]). The Federal government controls 93 percent of the land area. Mining, Federal installations, tourist and recreation activities, and grazing allotments all occur largely on public land in Nye County (Nye County Board of Commissioners, 1993). Esmeralda County covers approximately 9,295 km^2 (3,589 mi^2).

3.9.1 Population

The area around the NAFR and the NTS is sparsely populated. Table 3-1 lists the 1995 estimated populations for communities in the region of influence and the total populations for Nye and Esmeralda Counties.

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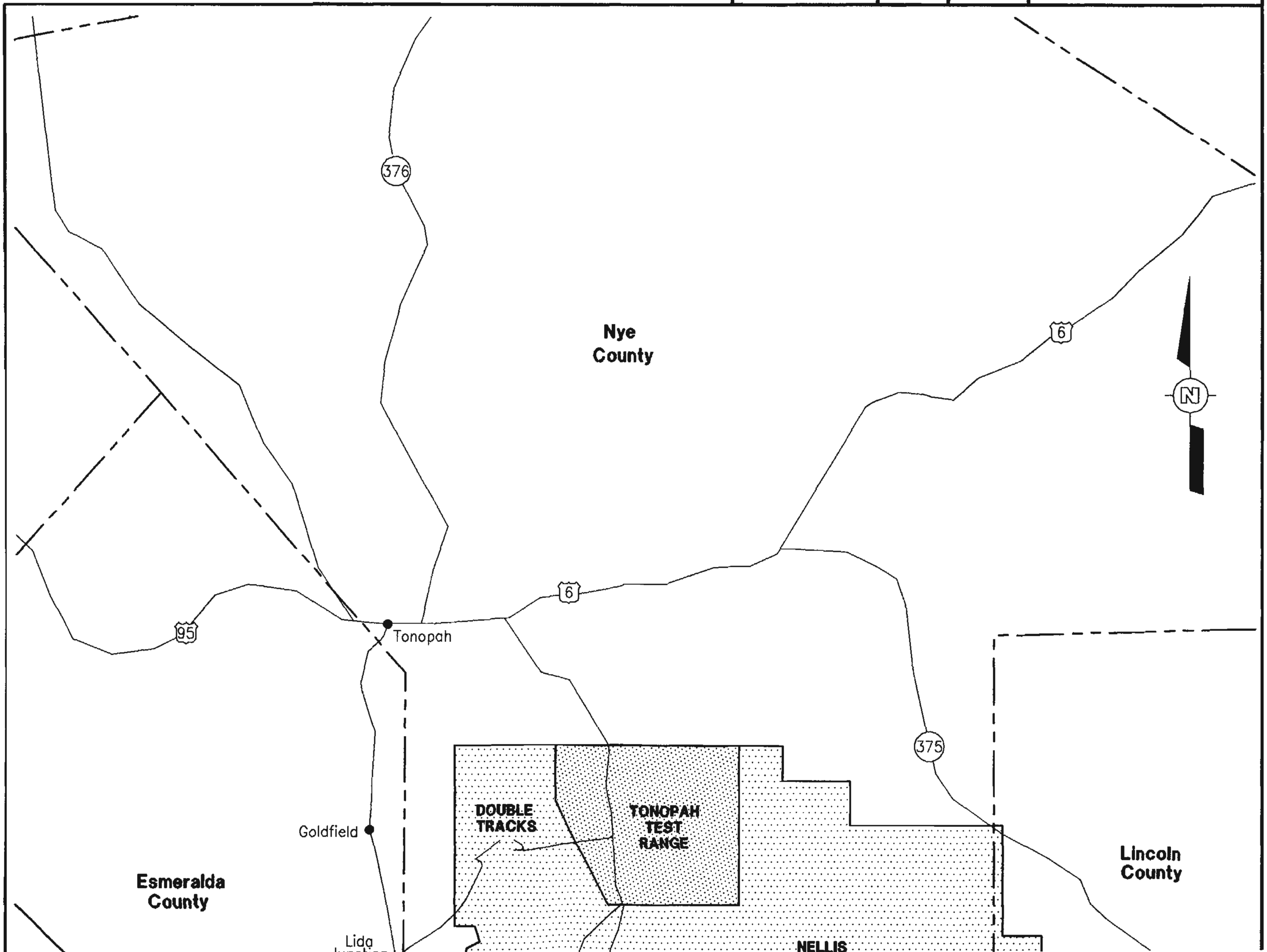

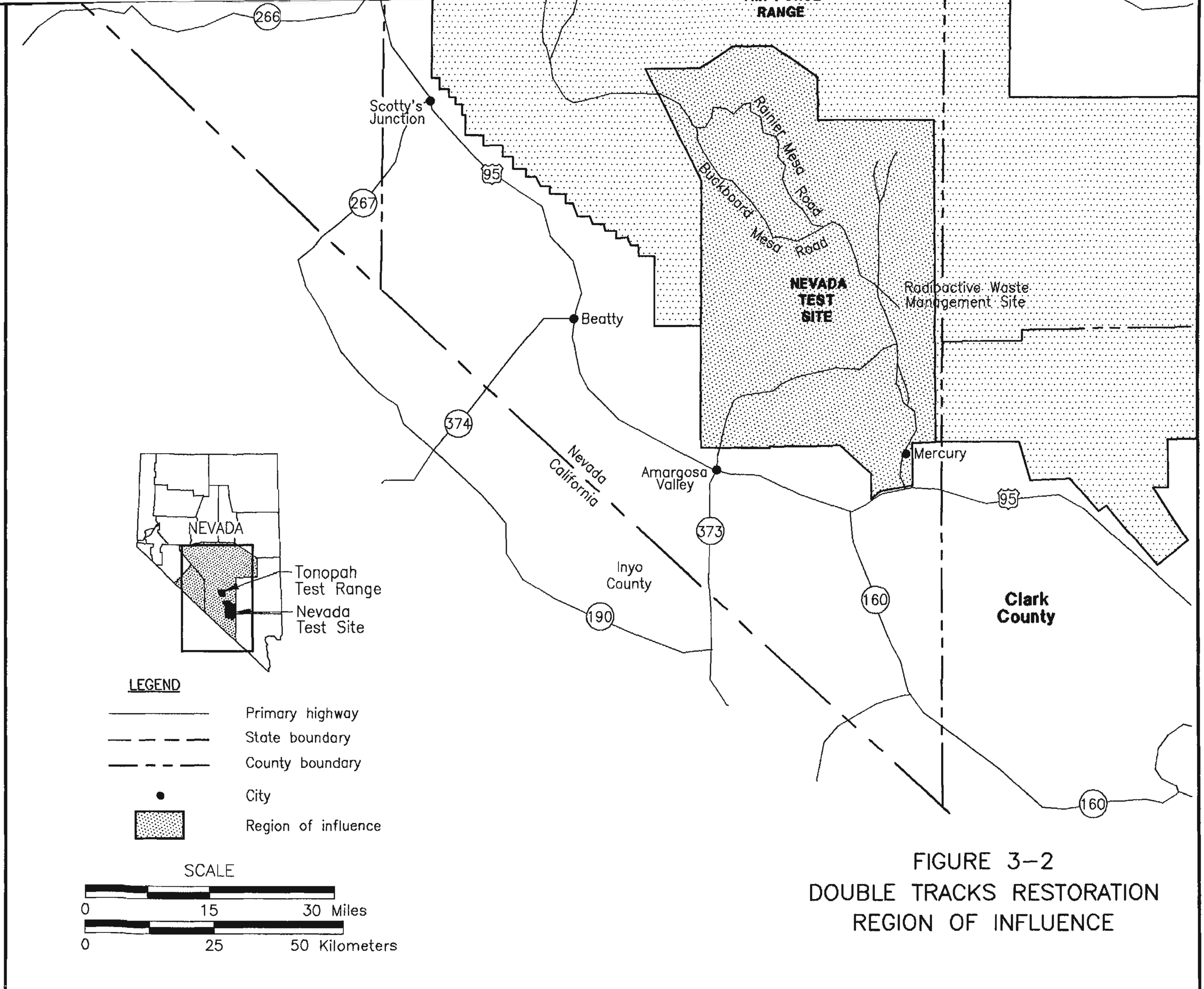

FIGURE 3-2
DOUBLE TRACKS RESTORATION
REGION OF INFLUENCE

Table 3-1
Populations of Communities in the Region of Influence

Community	1995 Population
Nye County	17,781
Tonopah	3,616
Beatty	1,652
Amargosa Valley	838
Esmeralda County	1,344
Goldfield	200

Source: Nye County Board of Commissioners, 1993; G. Blankenship, personal communication, 1995; U.S. Bureau of the Census, 1994.

3.9.2 Employment and Income

In 1990, the three largest employment sectors in Nye County were service industries (58.2 percent), mining (15.2 percent), and government (9.4 percent). From 1980 to 1990, total employment in Nye County grew from 7,860 to 12,889, for an average annual increase of 6.4 percent. This increase in employment consisted largely of employees who live outside Nye County, which accounts for the disparity between the civilian labor force (9,100 people) and the total number of jobs (12,889). According to the State of Nevada Employment Security Department, 8,780 members of the total labor force were employed and 320 members, or 3.6 percent, of the total labor force were unemployed. The unemployment rate for Nye County was lower than for the State (4.9 percent) and the nation (5.5 percent) (State of Nevada, 1990). In 1990, earnings in Nye County totaled 408.3 million dollars.

In 1990, the three largest employment sectors in Esmeralda County were wholesale and retail trade (19.6 percent), agriculture (8.6 percent), and public administration (6.2 percent). Total employment was 673 and the unemployment rate was 8.6 percent. In 1990, earnings in Esmeralda County totaled 13.1 million dollars.

3.9.3 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority and Low-Income Populations*, directs Federal agencies to detect and mitigate potentially disproportionately high and adverse human health or environmental effects of its planned programs, policies, and activities on minority and low-income populations to promote nondiscrimination among various population segments. The requirements of the Executive Order apply only to identified impacts.

Nye and Esmeralda Counties are only sparsely populated, and populations of minority and low-income people are most likely found in towns and other areas of population concentration. Populated areas are discussed in Section 3.9.1.

3.10 Traffic and Transportation

The Double Tracks site is located in an access-restricted area that is separated from public roadways. Although the NAFR has many unimproved roads, the highest traffic volumes on the north ranges are found on the TTR, a portion of the NAFR. Traffic within TTR takes place mainly on Main Road North (Figure 1-1). North of the main gate, Main Road North becomes Sandia Drive (State Route 504). Approximately 18 km (11 mi) outside the main gate, U.S. Highway 6 represents the closest directly linked major public transportation route. U.S. Highway 95 extends along the west and southwest border of the NAFR and is the closest major roadway to the Double Tracks site; however, no permanently maintained roadway directly links the project site and U.S. Highway 95.

Traffic along the portions of interest of U.S. Highways 6 and 95 is entirely within Nye and Esmeralda Counties. Traffic data from 1993 indicate that 6,440 vehicles travel daily on U.S. Highway 95 near the junction of U.S. Highways 6 and 95 in Tonopah. U.S. Highway 6 had an annual daily traffic volume of 2,125 vehicles just east of the junction. Although no high-traffic volume junctions are present along the portion of U.S. 95 Highway within Esmeralda County, an area of concern has been identified near the southern portion of Goldfield, where a sharp turn must be negotiated by vehicles. In addition, road conditions in this area are not consistent with interstate highways; however, the speed limit is greatly reduced to 40 km/hour (25 mph) through Goldfield. Within Goldfield, the annual average daily traffic volume along U.S. Highway 95 is 2,025 vehicles. Nye and Esmeralda Counties are characterized by rural/low population density (16 percent of State population/19 percent of State area) and combine for only 0.7 percent of the State's traffic accidents.

3.11 Waste Management and Public Health and Safety

At present, the approximate remaining capacities of the Area 3 Bulk RWMS and the Area 5 RWMS are 155,830 and 65,130 m^3 (203,820 and 85,186 yd^3), respectively. During Fiscal Year (FY) 1995, a total volume of 25,050 m^3 (32,760 yd^3) was accepted at both sites. Area 3 accepted

12,720 m^3 (16,640 yd^3) of bulk low-level waste, and Area 5 accepted 12,330 m^3 (16,120 yd^3) of low-level waste.

Potentially radioactive waste at or from the project site is limited to in situ contaminated soil. Under present conditions, the soil remains in place and is minimally affected by erosional factors such as wind or rain; the soil is relatively undisturbed because of the presence of vegetation and dry conditions. The restricted access of this area further limits the potential for adverse human health effects.

Because significant resuspension is likely to occur only when the desert surface is disturbed, negative impacts on the quality of public health and safety are unlikely due to present conditions at the project site. Future land use is expected to be restricted.

4.0 Environmental Consequences

The environmental consequences of environmental restoration activities at the Double Tracks site are discussed in this section. The impact analysis is based on a bounding scenario that includes remediation of a 3-ha (7.4-acre) area with disturbance of an additional 2-ha (5-acre) area for the staging area, remediation support areas, and well site clearing. Any additional negative or positive impacts due to the various alternatives are discussed as appropriate in each resource section.

4.1 Geology and Soils

Because the drilling of one water well is not expected to have any substantial impact, the proposed action and Alternatives 1, 2, and 3 would have no effect on the geology of the area.

Implementation of the proposed action and Alternatives 1, 2, and 3 would have impacts on the area soil. The proposed action would affect 4 ha (10 acres) of soil, including both the soil staging area and the contaminated soil areas. Vegetative cover would be removed, thereby increasing the potential for erosion. Soils in 3 ha (7.4 acres) would be stripped away. During the operational stage, erosion potential would be minimized through the use of engineered systems, such as construction of runoff control berms. After completion of operations, the soil would be treated with chemical soil stabilizers to ensure short-term stabilization, and long-term stabilization would be established through revegetation. Soil would also be disturbed in an additional 1 ha (2.5 acres) for the well site.

Alternatives 1 and 2 would create additional soil disturbance as a result of new road construction. Alternative 1 would require construction of approximately 48 km (30 mi) of new roadway, which would disturb an additional 29 ha (72 acres) of land within the NAFR. Alternative 2 would require construction of approximately 29 km (18 mi) of new roadway, which would disturb an additional 18 ha (44 acres) of land.

The no action alternative would involve no ground disturbance and no impacts to existing geologic features.

4.2 Microclimate Conditions

The proposed action and Alternatives 1, 2, and 3 would have temporary effects on the microclimatic conditions of the project site. Vegetation removal and grading of the surface would remove surface irregularities and result in very localized changes to microsite temperatures, humidity, insolation, and wind speeds. Although this could affect revegetation success on the site, no changes would be evident at distances a few meters from the disturbed areas.

The no action alternative would have no effect on the microclimatic conditions at the project site. No changes would occur to site vegetation, topography, temperature, humidity, insolation, or wind speeds.

4.3 Water Quality

The environmental consequences to surface water and groundwater due to environmental restoration activities at the project site are discussed in the following sections.

4.3.1 Surface Water

Operations associated with the proposed action and Alternatives 1, 2, and 3 would have no adverse environmental consequences on surface waters because no perennial streams, lakes, or ponds are present on or adjacent to the project site. After completion of the proposed action or Alternative 1, 2, or 3, the site would be recontoured and restored to help normalize any runoff that could potentially reach the terminal playa downgradient of the project site.

In addition, annual rainfall is about 15 cm (6 in.), and the impact on erosion should be minimal because the work is expected to be of short duration (30 to 60 days), during which time chemical stabilization would occur.

4.3.2 Groundwater

The proposed well for this project would produce a maximum of 757,000 L (200,000 gal) per day for the duration of the project, 60 ± 30 days. Withdrawals would be intermittent and short term and would not reach the maximum on many days. Following completion of the proposed remediation project, the USAF may continue to use this well intermittently for range construction and maintenance purposes. The resulting groundwater withdrawal is not expected to have any impact beyond some temporary lowering of the water table in the vicinity of the well during pumping.

If environmental restoration is not implemented at the site, the proposed well would not be constructed and the groundwater would not be pumped. Implementation of the no action alternative would also not provide for the contaminant removal. Although transport of plutonium to groundwater is essentially zero because the evapotranspiration rate is higher than the percolation rate for this area, some net downward movement of water could occur under rare circumstances. For such a case, the average concentration of plutonium in interstitial water would be approximately 40 pCi of plutonium-239 per liter of water and would be substantially diluted if it were ever to reach groundwater. This is equivalent to an ingestion dose of approximately 1 millirem per year to a member of the public if this groundwater were the only source of water and is less than the dose rate established by the U.S. Environmental Protection Agency for community drinking water.

4.4 Biological Resources

This section describes the potential environmental effects to natural resources.

4.4.1 Vegetation

Impacts to vegetation from activities associated with the proposed action and Alternatives 1, 2, and 3 should be minimal. Although vegetation would be removed from approximately 5 ha (12 acres), restoration operations in the project area would be followed immediately by stabilization and revegetation efforts. Short-term revegetation success would depend on irrigation and climatic factors during the time following treatment and seeding. Because it would involve the most new roadway construction (48 km [30 mi]), Alternative 1 would have the greatest impact on vegetation and would involve clearing an additional 29 ha (72 acres) of land. For Alternatives 1 and 2, the new roadway construction through the NAFR would represent a commitment of additional land. Prior to authorizing any activities that would disturb the ground surface, preactivity surveys by qualified biologists would be conducted to determine whether sensitive plant species are present. If sensitive species were found, attempts would be made to avoid them. Whenever possible, attempts would be made to revegetate with native species.

The no action alternative would result in the continued presence of contaminants in soils above 200 pCi/g. The potential for impacts to biological resources would remain at current levels. Ground distrubance and vegetation removal associated with the environmental restoration of this site would not occur.

4.4.2 Wildlife and Wild Horses

Small mammal, reptile, and bird populations would probably decline initially in the project area due to habitat destruction from soil stripping and human activities. However, these activities would have no effect on population viability in the valley. After the completion of revegetation measures, the animal populations in the stabilized area would eventually return to previous levels. Consequently, no long-term adverse impact is expected from environmental restoration activities. The no action alternative would have no effect on wildlife populations currently inhabiting the project area, and temporary ground disturbance associated with environmental restoration would not occur.

The proposed action and Alternatives 1, 2, and 3 would result in some minor road effects on wildlife populations. The effects would occur primarily adjacent to the road and would decrease, approaching preroad conditions, with increasing distance from the road. This road effect is typical but would likely be much less than expected with public highways because traffic counts would be considerably less on the proposed roads. The revegetation measures should mitigate any long-term impacts associated with the proposed action. Wild horses use this valley as a primary foraging area in the winter months. Project activities are expected to occur during the spring months of March to April. Although horse populations would still occupy areas near the project site, provided water is present during this time frame, the small amount of land involved in the proposed restoration project poses little threat to the wild horse population. The contaminated area that would be remediated is presently fenced, as it has been for decades, and poses no danger to the wild horses.

Alternative 1, and Alternative 2 to a lesser degree, would increase the potential for horse-vehicle collisions. The project-related increase in traffic on existing roads under the proposed action and Alternative 3 could also result in additional horse-vehicle collisions. However, increases in herd mortality due to collisions would be minor in all cases.

The no action alternative would result in no change to current impacts in the short-term, however, because of the remedial activities under the proposed action and action alternatives barriers, such as fences and cattle guards, could be removed in the future and would eliminate the potential for wild horse trapping. Potential increases in vehicle-horse collision would also not occur under the no action alternative (EG&G, 1994).

4.5 Air Quality

The activities associated with the proposed action and Alternatives 1, 2, and 3 would likely have only minimal impacts on air quality. Construction areas would be watered, as necessary, to help reduce fugitive dust due to heavy equipment activity. Vehicle and equipment emissions would also affect air quality in the project area, but these impacts would be minor and short term in nature. Subsequent to restoration operations, revegetation and soil stabilization would mitigate any future fugitive dust problems.

Alternatives 1 and 2 would likely generate the greatest volume of vehicular traffic because of the construction of new roadways and improvement of existing roadways. However, the newly constructed/improved roads would also reduce fugitive dust created by vehicles traveling along unpaved or dirt surfaces. In addition, the shorter distance traveled along the new roadways would result in lower vehicle emissions from load-carrying trucks.

In compliance with the National Emissions Standards for Hazardous Air Pollutants, modeling was conducted using the CAP 88 model approved by the U.S. Environmental Protection Agency. Additional information on the CAP 88 model run is presented in the human health effects section. Results indicated that the proposed action and all the alternative actions, including the no action alternative, would result in radiation exposures to the public of well below the 1.0-millirem-per- year dosage that would trigger the requirement for monitoring. The model was based on exposure to residents of the eastern part of the town of Goldfield, 13 miles west of the Double Tracks site; a duration of 2 months for the excavation disposal alternatives; and a duration of 12 months for the no action alternative. The model predicted that the worst-case scenario would be the no action alternative and would result in an annual dose rate of less than 0.006 millirem. Although such exposure is very low and is not the driver for this action, air contamination with plutonium would be less after completion of the interim corrective action.

The no action alternative would result in the continued presence of soils contaminated with plutonium and other radionuclides. Although, for this alternative, no air quality impacts would occur due to restoration activities, wind erosion of soil could result in contaminated airborne dust.

4.6 Land Use and Aesthetics

The proposed action and Alternatives 1, 2, and 3 could have minor effects on land use. Airspace use would be altered temporarily during site operations; however, subsequent to the implementation of the proposed action or Alternative 1, 2, or 3, the USAF would gain surface use of the land, which is presently restricted from any use. The route proposed for a new roadway under Alternative 1 has been under consideration by the USAF and consists partially of existing roads that would require improvement. Alternative 1 would likely result in a commitment of that land to roadway use. The improved access that would be generated by Alternatives 1 and 2 may precipitate other associated nearby land use changes over the long term.

The no action alternative would result in the continued presence of plutonium and other radionuclides at the Double Tracks site. Therefore, this area would remain fenced and unavailable for other uses. Land designated for new roads under the proposed action and Alternatives 1, 2, and 3 would be available for other uses if the no action alternative were selected.

Soil excavation and vegetation removal would disturb the natural environment in the project area, thereby causing contrasts in the color, tone, and texture of the landscape. Because the color or soil in the area tends to be light, denuding the soil would create color and tone contrasts visible for considerable distances. Short-term soil stabilization measures to control dust and permanent revegetation measures would likely rehabilitate the area of disturbance and reduce the duration of the visible disturbance of the landscape. Again, because it would involve the most new roadway construction, Alternative 1 would likely have the greatest impact. However, all areas that would be affected are outside public viewing positions, and the landscapes are generally lacking in high-value visual interest.

The no action alternative would involve no soil disturbance associated with environmental restoration of the site. The site would remain fenced, and aesthetics would not be impacted.

4.7 Historical and Cultural Resources

Impacts to any existing cultural resources in the project area could occur as a result of activities associated with the proposed action and Alternatives 1, 2, and 3. These activities include staging site preparation, removal of contaminated soil, transport of soil, and soil stabilization. Under Alternative 4, the no action alternative, cultural resources would not be impacted.

Avoidance is the preferred means of mitigating adverse effects to identified cultural resources. Prior to the construction or improvement of roads proposed under Alternatives 1, 2, and 3, records searches and preactivity surveys would be conducted to identify all cultural resources.

The significance of each is assessed in accordance with the guidelines set forth in 36 CFR 60.4 and is based on the inherent nature of the resource and its contextual integrity. If significant resources were found to exist, roads would be rerouted to avoid them wherever possible. If avoidance was not possible, the State Historic Preservation Officer would be consulted about mitigation.

With the no action alternative, any cultural resources on the site would remain undisturbed, and any damage to cultural resources from the radionuclide contamination in the soil would continue.

Additional text was suggested for inclusion by the Consolidated Group of Tribes and Organizations (CGTO) in relation to environmental consequences to cultural resources. The following text was taken from the Nevada Test Site Draft Environmental Impact Statement as requested by the CGTO.

> (If the proposed action is initiated), it is expected that American Indian cultural resources on the NAFR Complex will be adversely impacted if natural lands are scraped during environmental restoration. Access to culturally significant places will be increased if environmental restoration is successful, thus reducing Indian peoples' perception of health and spiritual risks associated with this area. Indian people wish to be involved in identifying environmental restoration methods and in the evaluation of restoration success (DOE, 1996).

4.8 Socioeconomic Considerations

Approximately 40 temporary, full-time construction and remediation jobs would be created in 1996 as a result of implementation of the proposed action or Alternative 1, 2, or 3. The majority of these jobs likely would be filled from the existing NTS workforce. Additional temporary workers could be hired from the local area. No population increase would be caused by the project, and workers would not expend monies or use services to any capacity that would greatly affect the local economies around the project area. No substantial health risks have been identified for any populations around the remediation area or the transportation routes; therefore, no disproportionate impacts would occur to any minority or low-income populations in the area.

With the no action alternative, employment at the NTS would continue at currently projected levels. Population growth rates would not change in the area and no risks to minority or low-income populations would occur.

4.9 Noise Considerations

Noise sources expected under the proposed action and Alternatives 1, 2, and 3 are associated with heavy equipment used for soil excavation and well construction. These sources would be concentrated around the remediation area and road construction sites. Noise levels 50 feet from typical noise sources would be as follows: drill rig - 90 decibels on the A-weighted scale (dBA), backhoe - 85 dBA, excavator - 80 dBA, bulldozer - 80 dBA, heavy trucks - 91 dBA, and soil compactor - 80 dBA. No sensitive public receptors are located within the impacted area. Only project workers and visitors would likely be closer than 50 feet to any noise source. Project workers and visitors would be required to follow Occupational Safety and Health Administration regulations for noise protection during all well drilling and remediation activities.

Additional noise generated by trucks along public highways would be temporary. Noise levels would not substantially increase above existing levels.

Subsequent to the restoration operations, aircraft-related noise levels may increase, but noise impacts to sensitive public receptors are not anticipated.

With the no action alternative, noise levels would not increase above present background levels at the Double Tracks site. Aircraft operations would constitute the major source of noise level increases above natural levels and would not be expected to have any negative impact.

4.10 Waste Management

Waste Management impacts to the Area 3 Bulk RWMS and the Area 5 RWMS would be minimal because the project would generate only a limited volume of waste requiring disposal. Using a worst-case soil expansion factor of 50 percent results in a total estimated waste volume of 1,860 m^3 (2,430 yd^3) from the Double Tracks site. If future waste acceptance volumes were to remain consistent with FY95, the waste volume from the Double Tracks site would account for a 15 percent increase over the total waste accepted at either facility.

Interim storage at the TTR under Alternative 3 is not expected to have any substantial impacts on that facility.

4.11 Human Health Effects

This section presents an analysis of the risk to the public and workers due to the remediation and transportation of plutonium-contaminated soil from the Double Tracks site to Area 3 of the NTS. Several scenarios, as detailed in Appendix B, were used to determine the estimated number of various consequences to human health associated with transportation that is required to support the proposed action and action alternatives. Although recent characterization data indicates that cleanup could encompass a smaller area, these risks are based on remediation of 3 ha (7.4 acres) at the 200 pCi/g and 7 ha (17.3 acres) at the 100-pCi/g level and are meant to be bounding (i.e., worst case) for both the public and workers.

Environmental remediation of soil contaminated with plutonium and other radionuclides would not occur if the no action alternative were selected. The site would remain fenced, and access to the site by workers and the public would continue to be restricted. The limited potential for contamination of groundwater and emission of contaminated dust outside the fenced area would continue. Risks associated with the excavation, remediation, and transportation of contaminated soils would not occur, but risk to an incidental intruder would continue.

4.11.1 Remediation Risk Assumptions

The remediation risk to workers was calculated for excavation of contaminated soils down to two cleanup levels (100 pCi/g and 200 pCi/g) under both routine and accident conditions. The risk calculation covers both radiation and non-radiation related health effects.

Worker risk can be obtained in the form of accident statistics related to specific industries from the U.S. Department of Labor (DOL) and other sources. For the activities that would be performed at the Double Tracks site, the DOE industrial labor classification of construction was used to estimate the injuries, illnesses and fatality rates per man-hour. From the classification and unit risk information gained from DOL statistics, risk models were constructed using the assumption that there is a linear relationship between total effort in man-hours and risk.

Cancer risks occur because workers are exposed directly to penetrating X-rays and gamma radiations of the radioisotopes associated with weapons-grade plutonium. In addition, the remediation workers could be exposed by inhalation to airborne plutonium. Through interpretation of existing data and by making assumptions about the anticipated conditions at the Double Tracks site, estimates of dose to onsite workers under normal conditions can be obtained.

Assumptions made for the analysis of both radiation and nonradiation human health effects to workers are as follows:

- Worker exposures to radiation under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable and that limit any individual's dose to less than 200 mrem per year.
- Risk of occupational injury per man-hour of excavation (construction labor classification) is $3.1x10^{-5}$ or 3 chances in 100,000 (U.S. Department of Labor [DOL], 1990).
- Risk of occupational fatality per man-hour of excavation (construction labor classification) is $5.5x10^{-8}$ or approximately 6 chances in 100 million (DOL, 1990).

- Excavation of 1 m^3 of soil is estimated to require 0.15 man-hour (assuming Level C personal protective equipment [PPE]) (DOE, 1995b).

- The volume of soil that would be excavated at the Double Tracks site to achieve a remediation action level of 200 pCi/g is 6,100 m^3 (7,980 yd^3). Soil removal for the 100-pCi/g level is anticipated to be 14,250 m^3 (18,640 yd^3).

- Data are reported as plutonium-239/240 in pCi/g. There is 10 times more plutonium-239 by activity than plutonium-240.

- The plutonium-239/240 ratio to americium-241 is 14:1 by activity.

- Uranium concentrations are not considered to contribute to risk (depleted).

- All workers are assumed to don PPE (i.e., powered air-purifying respirators) per the approved site-specific health and safety plan and, therefore, the risk due to inhalation of plutonium-239 is not considered.

- The maximum annual dose received by the workers is assumed to be similar to historical doses received at the NTS by REECo employees during past waste management activities. This maximum annual dose is 25 millirem (DOE, 1994). Assuming three full-time employees in addition to the drivers of the vehicles, the total person-millirem is 10 for the 200-pCi/g cleanup level and 25 for the 100-pCi/g cleanup level.

- Latent cancer fatality estimates are based on the BEIR V (National Academy of Sciences [NAS], 1990) cancer risk coefficients of $4x10^{-4}$ per person-rem for workers and $5x10^{-4}$ per person-rem for the general public. Radiation detriment estimates are based on the BEIR V (NAS, 1990) using a coefficient of $2x10^{-4}$ per person-rem.

Additionally, certain assumptions were made to evaluate human health effects to members of the public because of the potential for dust from the currently existing environment and from the remedial activities.

4.11.2 Remediation Risk Results

Risk was calculated based on the assumptions presented in Section 4.11.1. Results of the remediation risk analysis are presented in Tables 4-1 and 4-2. The dominant risks to workers are from fatal and nonfatal occupational accidents involving excavating and handling the soil using heavy equipment. Latent cancer fatalities and radiation detriment (i.e., noncancer adverse health effects as a result of exposure to radiation) represent extremely small risk. Because the results of the risk analysis indicate that the number of health effects in all instances would be less than one, workers engaged in this proposed project would not be expected to incur any harmful health effects during remediation operations.

Table 4-1
Remediation Risk for Cleanup Level of 100 pCi/g

Health Effect	Total Number of Health Effects
Fatalities due to Remediation Activities	0.0001
Injuries due to Remediation Activities	0.07
Latent Cancer Fatalities	0.00001
Radiation Detriment	0.000005

Table 4-2
Remediation Risk for Cleanup Level of 200 pCi/g

Health Effect	Total Number of Health Effects
Fatalities due to Remediation Activities	0.00005
Injuries due to Remediation Activities	0.03
Latent Cancer Fatalities	0.000004
Radiation Detriment	0.000002

Risk was also considered for individual members of the public. Impacts to human health could only occur through migration of the plutonium through air transport or transport to the groundwater. Because transport of plutonium to groundwater is essentially zero, no harmful health effects are anticipated. Air transport modeling predicted that the greatest annual dose rate to the public, in Goldfield, would be less than 0.006 millirem. This estimate was calculated from the CAP 88 model based on parameters which include: the distance from the source is 21 km (13 mi), wind direction is due east toward Goldfield, and the contaminated soil particulates were resuspended and transported to Goldfield by the wind with the dose receptors remaining in the plume centerline during the entire plume transport time. The case used for the model is intended to represent a worst case scenario. This annual dose was calculated for the no action alternative and equates to an estimated 0.000000003 latent cancer fatalities and 0.0000000012 radiation detriments through use of the dose to risk coefficients noted in the assumptions. Modeling for the proposed action and action alternatives estimated a dose to the public of 0.0054 millirem. Corresponding parameters as those used for the no action alternative were used with the added assumption that the mass loading of particles would be consistent with typical construction activities and would persist 16 hours per day for 60 days. Because the conditions modeled estimate public human health effects to be less than one for both the no action alternative and proposed action and action alternatives, human health impacts are not anticipated.

4.11.3 Transportation Risk Assumptions

The transportation risk to members of the public and the transport crew was calculated under routine and accident conditions using equations based on RADTRAN methodology. Calculation of the potential risk associated with transporting the Double Tracks waste involved evaluation of several scenarios within three major groups which include traffic accidents, routine transportation radiation exposure, and transportation accident radiation exposure. The overall risk is obtained by a summation over all of the possible scenarios. In all, twenty scenarios, which can be found in Appendix B, were evaluated by risk component. Shipments were evaluated based on many factors, including but not limited to: total amount of radioactivity of average shipment, number of shipments, population density along the transport corridor, distance of the shipment, average time spent at rest stops, average distance between stops, probability of an accident of certain severity occurring, and fraction of waste aerosolized in the case of a dispersal accident. The following assumptions were used to calculate the transportation risk:

- Population density along the transport route, including the suburban population assumed for Tonopah (0.5 mi) was estimated by the HIGHWAY code.
- The number of trips is the upper limit of the estimate (i.e., given 500 ± 200 round-trips, 700 trips would be used as an upper bound).
- The total number of shipments is based on 13 m^3 per shipment.
- The total distance used to calculate injuries and fatalities due to traffic accidents is based on a round-trip. The total distance used to calculate risks due to exposure to radiation is based on one-way trips.
- Risk coefficients for human health effects are taken from Nuclear Regulatory Commission and International Commission on Radiological Protection guidance and can be found in Appendix C.

4.11.4 Transportation Risk Results

The risk modeling for the Double Tracks waste transportation was performed to provide the expected number of human health effects along the transport corridor. The results of the transportation risk analysis are presented in Tables 4-3 through 4-6. These tables detail the type and number of health effects from transportation activities for each of the listed human health effects for both incident-free transport and transport with accidents. Small numbers are given in

Table 4-3
Transportation Risk for Cleanup Level of 100 pCi/g and Average Shipment Concentration of 350 pCi/g

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.018
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.15
Radiation-Related Health Effects under Routine Conditions			
Latent Cancer Fatalities	Public	2.48×10^{-5}	3.97×10^{-9}
	Transport Crew	1.36×10^{-5}	2.17×10^{-9}
Radiation Detriment	Public	2.48×10^{-5}	1.86×10^{-9}
	Transport Crew	1.36×10^{-5}	1.02×10^{-9}
Radiation-Related Health Effects under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	6.52×10^{-7}	2.60×10^{-10}
Radiation Detriment	Public and Transport Crew	6.52×10^{-7}	1.96×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	6.52×10^{-7}	2.15×10^{-9}
Early Radiation Injuries	Public and Transport Crew	6.52×10^{-7}	4.86×10^{-9}

scientific notation which is a mathematical representation of any decimal number as a number between one and ten raised to a specific power of ten (i.e., $1.36 \times 10^{-5} = 0.0000136$). Estimated dose is provided in the tables for the radiation related health effects. Although the number of human health effects are extremely small, virtually all the latent cancer fatality incidents under routine conditions would be due to exposure of members of the public along roadside stops. This risk could be mitigated by limiting truck stops to areas of low population density.

As Tables 4-3 through 4-6 indicate, injuries and fatalities due to traffic accidents are the dominant risk in transporting bulk shipments of plutonium-contaminated soil to Area 3 from the TTR. Because the results of the risk analysis indicate that the number of health effects in all instances would be less than one, members of the general public and the transport crew would not be anticipated to incur any harmful health effects. If the cleanup goal is set at 200 pCi/g

Table 4-4
Transportation Risk for Cleanup Level of 100 pCi/g and Average Shipment Concentration of 1,000 pCi/g

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.018
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.15
Radiation-Related Health Effects under Routine Conditions			
Latent Cancer Fatalities	Public	7.08×10^{-5}	1.13×10^{-8}
	Transport Crew	3.87×10^{-5}	6.19×10^{-9}
Radiation Detriment	Public	7.08×10^{-5}	5.30×10^{-9}
	Transport Crew	3.87×10^{-5}	2.90×10^{-9}
Radiation-Related Health Effects under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	1.86×10^{-6}	7.43×10^{-10}
Radiation Detriment	Public and Transport Crew	1.86×10^{-6}	5.57×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	1.86×10^{-6}	6.14×10^{-9}
Early Radiation Injuries	Public and Transport Crew	1.86×10^{-6}	1.24×10^{-8}

instead of 100 pCi/g, the number of transports would be reduced by approximately 50 percent, as would the injury and fatality incidence.

Because no waste would be transported under the no action alternative, risk to members of the public and to workers would not increase above present conditions.

Risk related to Alternatives 1, 2, and 3 would be bounded by the risk anticipated from the proposed action and the no action alternative. Because the routes used under these alternatives have shorter lengths and less distance traveled along public roadways, the potential for negative impacts to human health would be decreased based on data which indicates that the probability of an accident increase with distance traveled.

Table 4-5
Transportation Risk for Cleanup Level of 200 pCi/g and Average Shipment Concentration of 350 pCi/g

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.0076
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.0065
Radiation-Related Health Effects under Routine Conditions			
Latent Cancer Fatalities	Public	1.06×10^{-5}	1.70×10^{-9}
	Transport Crew	5.81×10^{-6}	9.29×10^{-10}
Radiation Detriment	Public	1.06×10^{-5}	7.97×10^{-10}
	Transport Crew	5.81×10^{-6}	4.35×10^{-10}
Radiation-Related Health Effects under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	2.79×10^{-7}	1.11×10^{-10}
Radiation Detriment	Public and Transport Crew	2.79×10^{-7}	8.37×10^{-11}
Early Radiation Fatalities	Public and Transport Crew	2.79×10^{-7}	9.20×10^{-10}
Early Radiation Injuries	Public and Transport Crew	2.79×10^{-7}	1.87×10^{-9}

4.12 Greater Cleanup Standards

The interim action cleanup standard of 200 pCi/g is expected to be conservative. The ultimate level likely to be established under the FFACO is expected to be 400 pCi/g, but could be as low as 100 pCi/g. In the latter case, some additional lateral excavation would be required, but the surficial area remediated to or below 200 pCi/g would be cleaned vertically to levels below the 100-pCi/g benchmark.

4.13 Cumulative Impacts

Because remediation of the Double Tracks site would be confined to a very small area, the activity would have a short duration, and transportation impacts would not appreciably contribute to public or occupational risk, cumulative impacts to the natural environment would be minimal. Appendix A provides a comparison of impacts by resource and alternative.

Table 4-6
Transportation Risk for Cleanup Level of 200 pCi/g and Average Shipment Concentration of 1,000 pCi/g

Health Effect	Affected Group	Dose (person-rem)	Total Number of Health Effects
Fatalities due to Traffic Accidents	Public and Transport Crew	NA	0.0076
Injuries due to Traffic Accidents	Public and Transport Crew	NA	0.065
Radiation-Related Health Effects under Routine Conditions			
Latent Cancer Fatalities	Public	3.03×10^{-5}	4.85×10^{-9}
	Transport Crew	1.66×10^{-5}	2.65×10^{-9}
Radiation Detriment	Public	3.03×10^{-5}	2.28×10^{-9}
	Transport Crew	1.66×10^{-5}	1.24×10^{-9}
Radiation-Related Health Effects under Accident Conditions			
Latent Cancer Fatalities	Public and Transport Crew	7.97×10^{-7}	3.19×10^{-10}
Radiation Detriment	Public and Transport Crew	7.97×10^{-7}	2.39×10^{-10}
Early Radiation Fatalities	Public and Transport Crew	7.97×10^{-7}	2.63×10^{-9}
Early Radiation Injuries	Public and Transport Crew	7.97×10^{-7}	5.34×10^{-9}

Under normal operating conditions, short-duration releases of air pollutants would occur due to equipment exhaust and particulate dust associated with vehicle movement on unpaved surfaces; however, dust control would mitigate most visible impacts on site. The remediation would have no appreciable impact to water resources, geology, biological resources, land use and aesthetics, socioeconomics, or historical and cultural resources.

The added risk to the public along the transport corridor due to transportation of the Double Tracks waste for the proposed action is extremely small. The estimated radiation dose that would be received by a member of the public, or transport crew is not anticipated to have any negative human health effects. Additionally, injuries or fatalities associated with traffic accidents during transport are not anticipated because the results of the risk analysis show the number of health effects would be less than one.

The proposed action would increase the volume accepted annually when compared to FY 95 at the Area 3 Bulk RWMS or Area 5 RWMS by approximately 15 percent. In accordance with NVO-325, all shippers are to notify NTS traffic control prior to shipping, and shipments can be delayed to alleviate any peak workloads, as necessary. However, impacts are not expected to be substantial due to the small increase and limited duration of the project.

The proposed action and the action alternative would provide long-term positive environmental impacts. Because of the remedial action, the limited potential for human health effects would be decreased. Some land use restraints could be lifted for U.S. Air Force operations in the short-term with additional potential for the public long-term. Additionally, the potential would exist for fences and barriers to be removed which would eliminate the potential for wild horse trapping.

5.0 Mitigation Measures

Mitigation is defined in CEQ regulations in 40 CFR 1508.20 and includes:

- Avoiding the impact altogether by not taking certain actions or parts of an action;
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
- Compensating for the impact by replacing or providing substitute resources or environments.

Some mitigation measures are identified or discussed in Chapter 2.0, Description of the Proposed Action and Alternatives, and Chapter 4.0, Environmental Consequences. The purpose of this chapter is to consolidate for the benefit of the reader the mitigation measures, some of which are interspersed among the two chapters. The mitigation measures to be used in this project are summarized by but are not limited to the following:

- Health and Safety
  - Provide routine health and safety training for all Double Tracks field personnel to meet the requirements of 40 CFR 264.16 and DOE orders and procedures
  - Require use of PPE by site workers where specified in the site-specific HASP
  - Require that workers follow appropriate decontamination procedures before leaving the contamination reduction zone
  - Comply with OSHA regulations in 29 CFR Part 1910.
- Cultural Resources
  - Avoid cultural resources as much as possible when implementing corrective action measures, especially excavation
  - If archeological or historical artifacts are discovered during site excavation activities, delay further surface or shallow subsurface disturbance and contact a qualified archeologist to make a site assessment

- Consult the State Historic Preservation Officer about further mitigation measures to be taken if avoidance of cultural resources is not possible.

- Operations Activities
  - Conduct regular measurements for contamination of material excavated to determine contaminant parameters prior to transport
  - Control dust and fugitive contaminant emissions during excavation using water and chemical surfactants as necessary
  - Treat roads traveled by vehicles transporting contaminated or clean soil with water sprays to control dust
  - Shut down all operations temporarily if unexpected changes in site conditions occur
  - Use high-pressure water or steam to wash contaminated equipment surfaces
  - Maintain containment zones during excavation to minimize contaminant migration from the project site.

- Reclamation of Disturbed Areas
  - Perform reclamation activities through treatment with chemical soil stabilizers and establish plant growth with preference given to native species.

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Appendix A

Comparison of the Proposed Action and Alternatives

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 1 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Geology and soils: Contaminated soils would be excavated and removed and a soil staging area would be created affecting a total of 4 hectares (ha) (10 acres). Minor changes to the contours of the project site will likely occur. The project site and all disturbed areas would be revegetated. No substantial adverse effects are anticipated.	***Geology and soils:*** Same as the proposed action; however, the additional road improvements would create short-term dust and disturb the soil in an additional 29 ha (72 acres). No substantial adverse impacts are foreseen.	***Geology and soils:*** Same as the proposed action; however, the road improvements, though less extensive than Alternative 1, 18 ha (44 acres), would create short-term fugitive dust.	***Geology and soils:*** Same as the proposed action.	***Geology and soils:*** No soil-disturbing activities would take place. Soils would remain contaminated.
Water Quality: Surface-water quality and groundwater quality are expected to remain unchanged. However, a well would withdraw 757,000 liters (ℓ) (200,000 gallons [gal]) of groundwater on intermittent days for the duration of the project, 60 ± 30 days.	***Water Quality:*** Same as the proposed action.	***Water Quality:*** Same as the proposed action.	***Water Quality:*** Same as the proposed action.	***Water Quality:*** The existing conditions would continue.

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 2 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Biological Resources: Existing vegetation would be removed from approximately 4 ha (10 acres); however, disturbed areas within the project site would be revegetated with native vegetation. During the operations, insects, avifauna, small mammals, and possibly wild horses may be temporarily disturbed and/or displaced; however, wildlife would very likely return after the activities conclude. There are no known threatened or endangered species of plant and wildlife in the project area or vicinity. No major or adverse impacts are foreseen.	***Biological Resources:*** Same as the proposed action. However, because of the additional new roads and improvements an additional 29 ha (72 acres) would be affected. No substantial and/or adverse impacts are foreseen.	***Biological Resources:*** Same as Alternative 1, but impacts will be less extensive because of shorter length road construction. An additional 18 ha (44 acres) would be disturbed beyond the proposed action.	***Biological Resources:*** Same as the proposed action.	***Biological Resources:*** The existing conditions would continue.

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 3 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS.	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Air Quality: Short-term fugitive dust would be created by the proposed soil excavation and removal activities. Standard dust suppression measures would be used. Vehicular air emissions would increase during excavation, removal, and waste transport activities. No human health effects to the public would be anticipated. Estimated dose because of dust would be less than no action. No long-term impacts are likely because the project area would be revegetated. No major and/or substantial impacts are likely to occur.	***Air Quality:*** Same as the proposed action. In addition, although increased fugitive dust would be created because of the new roadway, the shorter trip duration would result in less vehicular air emissions.	***Air Quality:*** Same as Alternative 1.	***Air Quality:*** Same as the proposed action.	***Air Quality:*** The area would remain undisturbed. With worst-case annual wind direction and speed Goldfield residents would receive an annual radiation dose of 0.006 millirem which would result in an estimated 0.000000003 latent cancer fatalities and 0.0000000012 radiation detriments, in effect causing no human health effects.

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 4 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Noise Considerations: Noise from site preparation, excavation, soil removal, transportation, and road improvements would occur. Project workers and visitors would be required to follow OSHA regulations to mitigate loud or impact sounds. However, no adverse noise impacts would affect sensitive receptors (i.e., human populations) because of the secured and isolated location of the project.	***Noise Considerations:*** Same as the proposed action.	***Noise Considerations:*** Same as the proposed action.	***Noise Considerations:*** Same as the proposed action.	***Noise Considerations:*** Noise levels would not increase above existing levels.
Land Use and Aesthetics: The proposed action would not change the long-term land use and visual resources on the project site. No adverse impacts are foreseen in these two areas. However, the removal of contaminated soils would make future land use options available, whereas the contaminated soils limit the use of the project site.	***Land Use and Aesthetics:*** Same as the proposed action.	***Land Use and Aesthetics:*** Same as the proposed action.	***Land Use and Aesthetics:*** Same as the proposed action.	***Land Use and Aesthetics:*** The existing conditions and land use restrictions would continue.

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 5 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Historical and Cultural Resources: Procedures are in place to mitigate impacts to significant cultural resources. Therefore, no adverse impacts are expected.	***Historical and Cultural Resources:*** Same as the proposed action. New road construction would likely follow existing jeep trails and/or disturbed areas.	***Historical and Cultural Resources:*** Same as the proposed action.	***Historical and Cultural Resources:*** Same as the proposed action.	***Historical and Cultural Resources:*** The existing conditions would continue.
Socioeconomic Considerations: The project should not result in substantial impacts. The number of workers that would be required would be about 40 temporary full-time workers over an estimated 2-month period. In addition, nearby towns would not likely be affected because project workers would not likely reside, expend monies, or use services in these towns. Minority and low-income populations would not experience significant health risks.	***Socioeconomic Considerations:*** Same as the proposed action.	***Socioeconomic Considerations:*** Same as the proposed action.	***Socioeconomic Considerations:*** Same as the proposed action.	***Socioeconomic Considerations:*** The existing socioeconomic conditions would continue.

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 6 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Traffic and Transportation: Traffic would increase slightly for a short term; however, no health effects to the public because of traffic accidents would be anticipated.	***Traffic and Transportation:*** Use of private roadways eliminates risk to the public. In addition, trucks would travel shorter distances to reduce risk to workers.	***Traffic and Transportation:*** Same as the proposed action. In addition, shorter mileage on public highways would reduce risk to the public and workers.	***Traffic and Transportation:*** Same as the proposed action.	***Traffic and Transportation:*** The existing traffic and transportation conditions would continue.
Waste Management: Acceptance of the Double Tracks waste would increase annual waste disposal at either the Area 3 or Area 5 RWMS by 15%. This amount is not expected to have any substantial impact.	***Waste Management:*** Same as the proposed action.	***Waste Management:*** Same as the proposed action.	***Waste Management:*** Interim storage at the TTR is not expected to have any substantial impact. Impact to NTS waste management facilities would be the same at the proposed action.	***Waste Management:*** Waste management acceptance would not be impacted by the Double Tracks remediation project.

Table A-1
Comparison of the Proposed Action and Alternatives
(Page 7 of 7)

Proposed Action Remediation with contaminated soil transport through Cactus Range, through the TTR road network, followed by use of public highways to the NTS	**Alternative 1** Remediation with contaminated soil transport via Nellis Air Force Range	**Alternative 2** Remediation with contaminated soil transport via Lida Junction	**Alternative 3** Remediation with contaminated soil transport to the TTR for interim storage	**Alternative 4** No Action Alternative contaminated soil remains in place
Human Health: Risk to public and workers would increase in the short term; however, human health effects are not expected to be substantial and/or adverse. At the anticipated 200 pCi/g cleanup level the greatest number of health effects to workers would be 0.03 injuries due to remediation activities. All health effects from remediation activities due to radiation are essentially zero. The greatest number of health effects to the public and the transport crew due to transportation of the Double Tracks waste would be 0.065 injuries due to traffic accidents. All health effects from the transportation due to radiation are essentially zero.	***Human Health:*** Same as the proposed action.	***Human Health:*** Same as the proposed action.	***Human Health:*** Same as the proposed action.	***Human Health:*** The existing conditions would continue.

Appendix B

Scenarios and Equations for the Double Tracks Site Soil Transportation Risk Assessment

B.1.0 Scenarios and Equations for the Double Tracks Site Soil Transportation Risk Assessment

This appendix describes the scenarios and presents the equations used to analyze the risks associated with the transportation of soil from the Double Track site to the Nevada Test Site (NTS). Definition of the parameters used in the risk assessment and referenced values for these parameters are presented in Appendix C.

B.1.1 Nomenclature

Component risks are indexed as R_{ab}, where

a = Scenario number, 1 through 20 (unique to each risk component), and
b = Health effect considered (f = fatality, in = injury, c = cancer, or d = noncancer radiation detriment).

Some parameters used in this risk assessment vary with population distribution (e.g., population density). These parameters are subscripted with the index (e.g., d_1) to indicate that they are population-distribution-specific. The indices i = 1, 2, and 3 indicate rural, suburban, and urban population distributions, respectively. The subscript α indicates a radionuclide-specific parameter (e.g., fractional activity of plutonium-239 in soil). The subscript index s indicates that a parameter is dependent on transportation accident severity.

This risk assessment divides the spectrum of transportation accidents into eight categories, in accordance with a U.S. Nuclear Regulatory Commission (NRC) report referred to as NUREG-0170 (NRC, 1977).

B.1.2 Summary of Scenarios

A summary of the scenarios used in this risk assessment is presented in Table B-1. The table lists the risk component number, which uniquely identifies the component, its name, a short scenario description, and the type of consequence inherent in the scenario.

Table B-1
Summary of Risk Components in the Double Tracks Site Transportation Risk Assessment
(Page 1 of 3)

Scenario Components	Description of Scenario
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	1 Risk of traffic accidents Fatalities due to impacts Fatalities
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	2 Risk of traffic accidents Injuries due to impacts Injuries
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	3 Cancer risk from routine transportation Risk to public near route taken by Double Tracks soil transports Cancers
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	4 Radiation detriment risk from routine transportation Risk to public near route taken by Double Tracks soil transports Noncancer health detriment
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	5 Cancer risk from routine transportation Risks to public during stops taken by Double Tracks soil transports Cancers
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	6 Radiation detriment risk from routine transportation Risk to public during stops taken by Double Tracks soil transports Noncancer health detriment
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	7 Cancer risk from routine transportation Risk to public traveling in the same direction as Double Tracks soil transports Cancers

Table B-1
Summary of Risk Components in the
Double Tracks Site Transportation Risk Assessment
(Page 2 of 3)

Scenario Components	Description of Scenario
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	8 Radiation detriment risk from routine transportation Risk to public traveling in the same direction as Double Tracks soil transports Noncancer health detriment
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	9 Cancer risk from routine transportation Risk to public traveling in the direction opposite the Double Tracks soil transports Cancers
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	10 Radiation detriment risk from routine transportation Risk to public traveling in the direction opposite the Double Tracks soil transports Noncancer health detriment
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	11 Cancer risk from routine transportation Risk to crew during transport Cancers
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	12 Radiation detriment risk from routine transportation Risk to crew during transport Noncancer health detriment
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	13 Risks due to nondispersal accidents Early fatalities due to nondispersal accidents Fatalities (radiation syndrome)
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	14 Risks due to nondispersal accidents Early health effects due to nondispersal accidents Injuries (radiation syndrome)

Table B-1
Summary of Risk Components in the
Double Tracks Site Transportation Risk Assessment
(Page 3 of 3)

Scenario Components	Description of Scenario
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	15 Cancer risks due to nondispersal accidents Radiation cancers due to nondispersal accidents Cancers
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	16 Risks due to nondispersal accidents Noncancer health detriment due to nondispersal accidents Noncancer health detriment
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	17 Risks due to dispersal accidents Early fatalities due to dispersal accidents Fatalities (radiation syndrome)
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	18 Risks due to dispersal accidents Early health effects due to dispersal accidents Injuries (radiation syndrome)
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	19 Cancer risks due to dispersal accidents Radiation cancers due to dispersal accidents Cancers
Risk Component Number: Risk Component Name: Risk Scenario: Risks Addressed:	20 Risks due to dispersal accidents Noncancer health detriment due to dispersal accidents Noncancer health detriment

B.1.3 Traffic Accident Scenarios

The scenarios presented in this section describe the consequences to the public and the crew of traffic accidents involving vehicles hauling Double Tracks site soil to the NTS. The accidental consequences are fatalities and injuries exclusively due to impacts in collisions or single vehicle accidents. No releases are considered. In view of the statistical data available, fatalities and injuries are treated separately, but injuries are not subdivided further into categories such as "severe" or "light" injuries.

B.1.3.1 Fatalities in Traffic Accidents

The risk of fatalities due to traffic accidents involving transports of Double Tracks site soil depends on the distance traveled, the number of shipments, and the fatal accident probability. Using the following symbols

p_{1f} = Linear probability density for an accident fatality (m^{-1}),
n_1 = Number of shipments of soil from the Double Tracks site,
L_1 = Distance traveled from the Double Tracks site to the NTS (m), and
R_{1f} = Traffic fatality risk due to Double Tracks site soil transport,

the traffic fatality risk is

$$R_{1f} = p_{1f} \; n_1 \, 2L_1 \, . \tag{1}$$

B.1.3.2 Injuries in Traffic Accidents

The risk of injuries due to traffic accidents involving transports of Double Tracks site soil depends on the distance traveled, the number of shipments, and the probability of an accident with injury. Using the following symbols

p_{1in} = Linear probability density for an injury per unit road length (m^{-1}),
n_1 = Number of shipments of soil from the Double Tracks site,
L_1 = Distance traveled from the Double Tracks site to the NTS (m), and
R_{2in} = Traffic injury risk due to Double Tracks site soil transport,

the traffic injury risk is

$$R_{2in} = p_{1in} \; n_1 \; 2L_1 \, . \tag{2}$$

B.1.4 Routine Transportation Radiation Exposure Scenarios

The scenarios presented in this section evaluate public exposures of people living along the transport corridor or driving on the same road (Neuhauser and Kanipe, 1992). In this case, only exposure to penetrating gamma radiation is of interest. No evaluation for routine exposure to chemicals is necessary because of negligible routine emissions.

B.1.4.1 Scenarios for Radiation Exposures Along the Transport Corridor

These scenarios consider the exposure to penetrating gamma rays of people living along the band defined by a minimum and maximum distance from the center of the road.

B.1.4.1.1 Radiation Exposures Leading to Cancer

Here, the scenario leads to exposures resulting in an excess incidence in all kinds of cancer. With indices i = 1, 2, 3, indicating rural areas, suburban areas, and urban areas, respectively, and using the following variables

q_{r1}	=	Total amount of radioactivity of average shipment (Bq),
n_1	=	Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$	=	Fraction of total activity due to radioisotope α,
A	=	Total number of different radioisotopes α,
V_{vi}	=	Vehicle speed in area i ($m\ s^{-1}$),
d_i	=	Population density in area i (m^{-2}),
$r_{i\,min}$	=	Minimum integration distance from transport in area i (m),
$r_{i\,max}$	=	Maximum integration distance from transport in area i (m),
f_{1i}	=	Fraction of travel in area i,
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),
ϕ_{rc}	=	Dose-rate effectiveness factor for cancer at low dose rates,
a_{rc}	=	Risk coefficient for radiation-caused cancer (Sv^{-1}), and
R_{3c}	=	Cancer risk due to shipment of Double Tracks site soil,

the cancer risk for persons exposed along the transport route is

$$R_{3c} = \left[q_{r1}\ n_1\right] \left\{ \sum_{i=1}^{3} \frac{d_i}{V_{vi}}\ ln\left(\frac{r_{i\,max}}{r_{i\,min}}\right) f_{1i}\ L_1 \right\} \left(\sum_{\alpha=1}^{A} f_{r\alpha}\ \Phi_{er\alpha} \right) \frac{a_{rc}}{\phi_{rc}} . \qquad (3)$$

B.1.4.1.2 Exposures Leading to Noncancer Radiation Detriment

Here, the scenario leads to detriments such as lifetime shortening and genetic or teratogenic effects. With indices i = 1, 2, 3, indicating rural areas, suburban areas, and urban areas, respectively, and using the following variables

q_{r1} = Total amount of radioactivity of average shipment (Bq),
n_1 = Number of shipments of soil from the Double Tracks Site,
$f_{r\alpha}$ = Fraction of total activity due to radioisotope α,
A = Total number of different radioisotopes α,
V_{vi} = Vehicle speed in area i (m s^{-1}),
d_i = Population density in area i, (m^{-2}),
$r_{i\,min}$ = Minimum integration distance from transport in area i (m),
$r_{i\,max}$ = Maximum integration distance from transport in area i (m),
f_{1i} = Fraction of travel in area i,
L_1 = Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$ = External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
ϕ_{rd} = Dose-rate effectiveness factor for noncancer detriment at low dose rates,
a_{rd} = Risk coefficient for noncancer radiation detriment (Sv^{-1}), and
R_{4d} = Risk for noncancer radiation detriment,

the risk for radiation detriment other than cancer in persons exposed along the transport route is

$$R_{4d} = \left[q_{r1}\ n_1\right] \left\{ \sum_{i=1}^{3} \frac{d_i}{V_{vi}}\ ln\left(\frac{r_{i\,max}}{r_{i\,min}}\right) f_{1i}\ L_1 \right\} \left(\sum_{\alpha=1}^{A} f_{r\alpha}\ \Phi_{er\alpha} \right) \frac{a_{rd}}{\phi_{rd}} . \tag{4}$$

B.1.4.2 Scenarios for Radiation Exposures During Roadside Stops

These scenarios consider the exposure to penetrating gamma rays of persons exposed during roadside stops of the Double Tracks soil transport vehicles (Neuhauser and Kanipe, 1992).

B.1.4.2.1 Radiation Exposures Leading to Cancer

Here, the scenario leads to public exposures during roadside stops of the transport vehicles, resulting in an excess incidence in all kinds of cancer. Using the following variables

q_{r1} = Total amount of radioactivity of average shipment (Bq),
n_1 = Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$ = Fraction of total activity due to radioisotope α,
F_{ar} = Attenuation and geometric factors for public at rest stops,
A = Total number of different radioisotopes α,
N_2 = Average number of people exposed at rest stops,
t_1 = Average time spent at rest stops (s),
L_1 = Distance transported from the Double Tracks site to the NTS (m),
L_2 = Average distance between stops (m),
$r_{rms\,p}$ = Root-mean-square distance of the public at rest stops (m),
$\Phi_{er\alpha}$ = External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
ϕ_{rc} = Dose-rate effectiveness factor for cancer at low dose rates,
a_{rc} = Risk coefficient for radiation-caused cancer (Sv^{-1}), and
R_{5c} = Cancer risk due to exposure of public at roadside stops,

the cancer risk for persons exposed in public rest areas along the transport route is

$$R_{5c} = \left[q_{r1} \; n_1 \right] \frac{F_{ar}}{r^2_{rms\,p}} \; t_1 \; \frac{L_1}{L_2} \; N_2 \left(\sum_{\alpha = 1}^{A} f_{r\alpha} \; \Phi_{er\alpha} \right) \frac{a_{rc}}{\phi_{rc}} \, . \tag{5}$$

B.1.4.2.2 Exposures Leading to Noncancer Radiation Detriment

Here, the scenario leads to exposures resulting in an excess incidence in all kinds of radiation-induced effects other than cancer. Using the following variables

q_{r1} = Total amount of radioactivity of average shipment (Bq),
n_1 = Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$ = Fraction of total activity due to radioisotope α,
F_{ar} = Attenuation and geometric factors for public at rest stops,
A = Total number of different radioisotopes α,
$r_{rms\,p}$ = Root-mean-square distance of public at rest stops (m),
N_2 = Average number of people exposed at rest stops,

t_1 = Average time spent at rest stops (s),
L_1 = Distance transported from the Double Tracks site to the NTS (m),
L_2 = Average distance between stops (m),
$\Phi_{er\alpha}$ = External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
ϕ_{rd} = Dose-rate effectiveness factor for noncancer detriment at low dose rates,
a_{rd} = Risk coefficient for noncancer radiation detriment (Sv^{-1}), and
R_{6d} = Risk for noncancer radiation detriment,

the risk of noncancer radiation detriment to persons exposed in public rest areas along the transport route is

$$R_{6c} = \left[q_{r1} \ n_1 \right] \frac{F_{ar}}{r^2_{rms\,p}} \ t_1 \ \frac{L_1}{L_2} \ N_2 \left(\sum_{\alpha=1}^{A} f_{r\alpha} \ \Phi_{er\alpha} \right) \frac{a_{rd}}{\phi_{rd}} . \tag{6}$$

B.1.4.3 Scenarios for Radiation Exposures During Travel Parallel to Shipments

These scenarios consider the exposure to penetrating gamma rays of persons exposed traveling in the same direction as the Double Tracks soil transport vehicles (Neuhauser and Kanipe, 1992).

B.1.4.3.1 Radiation Exposures Leading to Cancer

Here, the scenario leads to exposures resulting in an excess incidence in all kinds of cancer. Using the following variables

q_{r1} = Total amount of radioactivity of average shipment (Bq),
n_1 = Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$ = Fraction of total activity due to radioisotope α,
A = Total number of different radioisotopes α,
N_3 = Average number of people in vehicles on the road,
t_2 = Average time needed for the vehicle to close the transport vehicle(s),
N_{4i} = One-way vehicle count rate in area i (s^{-1}),
F_{ap} = Attenuation factor of the transport vehicle for exposure of the public,
f_{1i} = Fraction of travel in area i,
f_{10i} = Fraction of freeway travel in area i,

g_{10i} = Fraction of rush hour travel in area i,
h_{10i} = Fraction of city street travel in area i,
V_{vi} = Transport speed in area i (m s^{-1}),
x_i = Minimum exposure distance in area i (m),
L_1 = Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$ = External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
ϕ_{rc} = Dose-rate effectiveness factor for cancer at low dose rates,
a_{rc} = Risk coefficient for radiation-caused cancer (Sv^{-1}), and
R_{7c} = Cancer risk due to travel parallel to shipments,

the cancer risk for persons exposed while traveling on the transport route in the same direction as the transport vehicles is

$$R_{7c} = \left[q_{r1} \; n_1\right] F_{ap} \; N_3 \left\{ \sum_{i=1}^{3} N_{4i} \left(f_{1i} \; L_1\right) \left(H_{10i} + G_{10i}\right)\right\} \left(\sum_{\alpha=1}^{A} f_{r\alpha} \; \Phi_{er\alpha} \right) \frac{a_{rc}}{\phi_{rc}} \; . \qquad (7)$$

The auxiliary functions H_{10i} in equation (7) are defined by

$$H_{10\,1} = \frac{1}{V_{v1}^{3} \; t_2} \; , \qquad (8)$$

and

$$H_{10\,2} = f_{10\,2} \left(\frac{16\, g_{10\,2}}{t_2\, V_{\nu 2}^3} + \frac{1 - g_{10\,2}}{t_2\, V_{\nu 1}^3} \right) + \left(1 - f_{10\,2}\right) \frac{15\, g_{10\,2} + 1}{t_2\, V_{\nu 2}^3} , \tag{9}$$

and

$$H_{10\,3} = \left(1 - h_{10\,3}\right) \left(\frac{16\, g_{10\,3}}{t_2\, V_{\nu 2}^3} + \frac{1 - g_{10\,3}}{t_2\, V_{\nu 1}^3} \right) + h_{10\,3} \frac{15\, g_{10\,3} + 1}{t_2\, V_{\nu 3}^3} . \tag{10}$$

The auxiliary functions $G_{10\,i}$ in equation (7) are defined by

$$G_{10\,1} = \frac{1}{2\, V_{\nu 1}^2} \left(\frac{1}{x_1} - \frac{1}{t_2\, V_{\nu 1}} \right) , \tag{11}$$

and

$$G_{10\,2} = f_{10\,2} \left[\frac{4\, g_{10\,2}}{V_{v\,2}^2} \left(\frac{1}{x_2} - \frac{2}{V_{v\,2}\, t_2} \right) + \frac{1 - g_{10\,2}}{2\, V_{v\,1}^2} \left(\frac{1}{x_2} - \frac{1}{V_{v\,1}\, t_2} \right) \right] + \left(1 - f_{10\,2}\right) \left[\frac{4\, g_{10\,2}}{V_{v\,2}^2} \left(\frac{1}{x_2} - \frac{2}{V_{v\,2}\, t_2} \right) + \frac{1 - g_{10\,2}}{2\, V_{v\,2}^2} \left(\frac{1}{x_2} - \frac{1}{V_{v\,2}\, t_2} \right) \right], \tag{12}$$

and

$$G_{10\,3} = \left(1 - h_{10\,3}\right) \left[\frac{4\, g_{10\,3}}{V_{v\,2}^2} \left(\frac{1}{x_3} - \frac{2}{V_{v\,2}\, t_2} \right) + \frac{1 - g_{10\,3}}{2\, V_{v\,1}^2} \left(\frac{1}{x_3} - \frac{1}{V_{v\,1}\, t_2} \right) \right] + h_{10\,3} \left[\frac{4\, g_{10\,3}}{V_{v\,3}^2} \left(\frac{1}{x_3} - \frac{2}{V_{v\,3}\, t_2} \right) + \frac{1 - g_{10\,3}}{2\, V_{v\,3}^2} \left(\frac{1}{x_3} - \frac{1}{V_{v\,3}\, t_2} \right) \right]. \tag{13}$$

B.1.4.3.2 Exposures Leading to Noncancer Radiation Detriment

Here, the scenario leads to exposures resulting in an excess incidence in all kinds of radiation induced effects other than cancer. Using the following variables

q_{r1}	=	Total amount of radioactivity of average shipment (Bq),
n_1	=	Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$	=	Fraction of total activity due to radioisotope α,
A	=	Total number of different radioisotopes α,
N_3	=	Average number of people in vehicles on the road,
t_2	=	Average time needed for the vehicle to close the transport vehicle(s),
N_{4i}	=	One-way vehicle count rate in area i (s^{-1}),
F_{ap}	=	Attenuation factor of the transport vehicle for exposure of the public,
f_{1i}	=	Fraction of travel in area i,
f_{10i}	=	Fraction of freeway travel in area i,
g_{10i}	=	Fraction of rush hour travel in area i,
h_{10i}	=	Fraction of city street travel in area i,
V_{vi}	=	Transport speed in area i ($m\ s^{-1}$),
x_i	=	Minimum exposure distance in area i (m),
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),
ϕ_{rd}	=	Dose-rate effectiveness factor for noncancer detriment at low dose rates,
a_{rd}	=	Risk coefficient for noncancer radiation detriment (Sv^{-1}), and
R_{8d}	=	Risk for radiation detriment due to travel parallel to shipments,

the risk for noncancer radiation detriment in members of the public exposed while traveling on the transport route in the same direction as the transport vehicles is

$$R_{8d} = \left[q_{r1}\ n_1 \right] F_{ap}\ N_3 \left\{ \sum_{i=1}^{3} N_{4i}\ (f_{1i}\ L_1)(H_{10i} + G_{10i}) \right\} \left(\sum_{\alpha=1}^{A} f_{r\alpha}\ \Phi_{er\alpha} \right) \frac{a_{rd}}{\phi_{rd}} . \tag{14}$$

The auxiliary quantities H_{10i} and G_{10i} are defined by equations (8) through (13).

B.1.4.4 Scenarios for Radiation Exposure During Travel Opposite to Shipments

These scenarios consider the exposure to penetrating gamma rays of persons exposed traveling in the direction opposite the Double Tracks soil transport vehicles (Neuhauser and Kanipe, 1992).

B.1.4.4.1 Radiation Exposure Leading to Cancer

Here, the scenario leads to exposures resulting in an excess incidence in all kinds of cancer. Using the following variables

q_{r1}	=	Total amount of radioactivity of average shipment (Bq),
n_1	=	Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$	=	Fraction of total activity due to radioisotope α,
A	=	Total number of different radioisotopes α,
N_3	=	Average number of people in vehicles on the road,
N_{4i}	=	One-way vehicle count rate in area i (s^{-1}),
F_{ap}	=	Attenuation factor of the transport vehicle for exposure of the public,
f_{1i}	=	Fraction of travel in area i,
f_{10i}	=	Fraction of freeway travel in area i,
g_{10i}	=	Fraction of rush hour travel in area i,
h_{10i}	=	Fraction of city street travel in area i,
V_{vi}	=	Transport speed in area i ($m\ s^{-1}$),
x_i	=	Minimum exposure distance in area i (m),
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),
ϕ_{rc}	=	Dose-rate effectiveness factor for cancer at low dose rates,
a_{rc}	=	Risk coefficient for radiation-caused cancer (Sv^{-1}), and
R_{9c}	=	Cancer risk due to travel opposite to shipments,

the cancer risk for persons exposed while traveling on the transport route in the direction opposite the transport vehicles is

$$R_{9c} = \left[q_{r1} \; n_1 \right] \frac{\pi}{2} F_{ap} \; N_3$$

$$\left\{ \sum_{i=1}^{3} N_{4i} \left(f_{1i} \; L_1 \right) I_{10i} \right\}$$

$$\left(\sum_{\alpha=1}^{A} f_{r\alpha} \; \Phi_{er\alpha} \right) \frac{a_{rc}}{\phi_{rc}} . \tag{15}$$

The auxiliary functions I_{10i} in equation (15) are defined by

$$I_{10\,1} = \frac{1}{V_{v1}^{2}} \left(\frac{f_{10\,1}}{x_1} + \frac{1 - f_{10\,1}}{x_2} \right) , \tag{16}$$

and

$$I_{10\,2} = \frac{f_{10\,2}}{x_1} \left(\frac{8 \; g_{10\,2}}{V_{v2}^{2}} + \frac{1 - g_{10\,2}}{V_{v1}^{2}} \right) + \frac{1 - f_{10\,2}}{x_2} \; \frac{7 \; g_{10\,2} + 1}{V_{v2}^{2}} , \tag{17}$$

and

$$I_{10\,3} = \frac{1 - h_{10\,3}}{x_2} \left(\frac{8\,g_{10\,3}}{V_{v2}^2} + \frac{1 - g_{10\,3}}{V_{v1}^2} \right) + \frac{h_{10\,3}}{x_3} \frac{7\,g_{10\,3} + 1}{V_{v3}^2} . \tag{18}$$

B.1.4.4.2 Exposures Leading to Noncancer Radiation Detriment

Here, the scenario leads to exposures resulting in an excess incidence in all kinds of radiation-induced effects other than cancer. Using the following variables

q_{r1}	=	Total amount of radioactivity of average shipment (Bq),
n_1	=	Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$	=	Fraction of total activity due to radioisotope α,
A	=	Total number of different radioisotopes α,
N_3	=	Average number of people in vehicles on the road,
N_{4i}	=	One-way vehicle count rate in area i (s^{-1}),
F_{ap}	=	Attenuation factor of the transport vehicle for the exposure of the public,
f_{1i}	=	Fraction of travel in area i,
f_{10i}	=	Fraction of freeway travel in area i,
g_{10i}	=	Fraction of rush hour travel in area i,
h_{10i}	=	Fraction of city street travel in area i,
V_{vi}	=	Transport speed in area i ($m\ s^{-1}$),
x_i	=	Minimum exposure distance in area i (m),
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),
ϕ_{rd}	=	Dose-rate effectiveness factor for noncancer detriment at low dose rates,
a_{rd}	=	Risk coefficient for noncancer radiation detriment (Sv^{-1}), and
R_{10d}	=	Risk for noncancer radiation detriment due to travel opposite to shipment,

the risk for noncancer radiation detriment in persons exposed while traveling on the transport route in the direction opposite the transport vehicles is

$$R_{10d} = \left[q_{r1} \; n_1 \right] \frac{\pi}{2} \; F_{ap} \; N_3 \left\{ \sum_{i=1}^{3} N_{4i} \left(f_{1i} \; L_1 \right) I_{10i} \right\} \left(\sum_{\alpha=1}^{A} f_{r\alpha} \; \Phi_{er\alpha} \right) \frac{a_{rd}}{\phi_{rd}} , \tag{19}$$

The auxiliary functions I_{10i} are defined by equations (16) through (18).

B.1.4.5 Scenarios for Radiation Exposure of the Transport Vehicle Crew

These scenarios consider the exposure to penetrating gamma rays of the crew traveling in the transport vehicle (Neuhauser and Kanipe, 1992). The risk calculation takes into account mutual shielding of the sources and attenuation by distance.

B.1.4.5.1 Radiation Exposure Leading to Cancer

Here, the scenario leads to exposures of the transport crew, resulting in an excess incidence in all kinds of cancer. Using the following variables

q_{r1}	=	Total amount of radioactivity of average shipment (Bq),
n_1	=	Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$	=	Fraction of total activity due to radioisotope α,
F_{sc}	=	Source shape factor for the crew exposure,
F_{ac}	=	Attenuation and geometric factors for the crew,
r_{rmsc}	=	Root-mean-square distance source to crew (m),
A	=	Total number of different radioisotopes α,
N_5	=	Average number of crew in transport vehicles,
f_{1i}	=	Fraction of travel in area i,
V_{vi}	=	Transport speed in area i (m s^{-1}),
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
ϕ_{rc}	=	Dose-rate effectiveness factor for cancer at low dose rates,

a_{rc}	=	Risk coefficient for radiation caused cancer (Sv^{-1}), and
R_{11c}	=	Cancer risk for the transport vehicle crew,

the cancer risk for the crew exposed during the transport is

$$R_{11c} = \left[q_{r1} \; n_1 \right] \frac{F_{sc} \; F_{ac}}{r^2_{rms\,c}} \; N_5 \left(L_1 \sum_{i=1}^{3} \frac{f_{1i}}{V_{vi}} \right) \left(\sum_{\alpha=1}^{A} f_{r\alpha} \; \Phi_{er\alpha} \right) \frac{a_{rc}}{\phi_{rc}} \; . \tag{20}$$

B.1.4.5.2 Exposures Leading to Noncancer Radiation Detriment

Here, the scenario leads to exposures of the transport crew resulting in an excess incidence in all kinds of radiation-induced effects other than cancer. Using the following variables

q_{r1}	=	Total amount of radioactivity of average shipment (Bq),
n_1	=	Number of shipments of soil from the Double Tracks site,
$f_{r\alpha}$	=	Fraction of total activity due to radioisotope α,
F_{sc}	=	Source shape factor for the crew exposure,
F_{ac}	=	Attenuation and geometric factors for the crew,
r_{rmsc}	=	Root-mean-square distance of source to crew (m),
A	=	Total number of different radioisotopes α,
N_5	=	Average number of crew in transports,
f_{1i}	=	Fraction of travel in area i,
V_{vi}	=	Transport speed in area i ($m\ s^{-1}$),
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),
ϕ_{rd}	=	Dose-rate effectiveness factor for noncancer detriment at low dose rates,
a_{rd}	=	Risk coefficient for noncancer radiation detriment (Sv^{-1}), and
R_{12d}	=	Risk for noncancer radiation detriment,

the noncancer risk for workers exposed while traveling on the transport vehicles is

$$R_{12d} = \left[q_{r1} \, n_1 \right] \frac{F_{sc} \, F_{ac}}{r^2_{rmsc}} \, N_5 \left(L_1 \sum_{i=1}^{3} \frac{f_{1i}}{V_{vi}} \right)$$

$$\left(\sum_{\alpha=1}^{A} f_{r\alpha} \, \Phi_{er\alpha} \right) \frac{a_{rd}}{\Phi_{rd}} . \qquad (21)$$

B.1.5 Transportation Accident Radiation Exposure Scenarios

The accidents discussed here are the same as those considered in RADTRAN IV (Neuhauser and Kanipe, 1992). The amount of radioactive material released in an accident depends on the severity of the accident, the physicochemical properties of the waste, and the characteristics of the transport vehicle and the containment package. Nondispersal accidents that breach the containment are assumed to produce a closely distributed amount of waste, whereas dispersal accidents involve the mobilization and aerosolization or vaporization of some waste components, with subsequent atmospheric dispersion (Harwood et al., 1991).

B.1.5.1 Scenarios for Radiation Exposures due to Accidents Without Waste Dispersion

In nondispersal accident scenarios, the breach of containment at the accident scene may lead to exposures of people nearby, such as members of the public or emergency response personnel. The agents of concern in an accident are radioisotopes with penetrating gamma radiation. In rare severe cases, radiation exposures may be high enough to cause early health effects such as radiation sickness, also called bone-marrow syndrome (International Commission on Radiological Protection [ICRP], 1990).

B.1.5.1.1 Early Radiation-Caused Fatalities in Nondispersal Accidents

Early health effects due to bone-marrow syndrome in accidents involving Double Tracks soil transport vehicles are assumed to be fatal in only an extremely small fraction of accidents. Using the symbols

p_{2is} = Linear probability density for an accident of severity s in area i (m^{-1}),
n_1 = Number of shipments of soil from the Double Tracks site,

q_{r1} = Total amount of radioactivity per average shipment (Bq),
f_{2s} = Fraction of waste released in accident of severity s,
r_{rmsb} = Root-mean-square distance for people at the accident scene (m),
F_{sa} = Source shape factor for released and enclosed activity,
S = Number of degrees of accident severity,
N_{6i} = Average number of persons significantly exposed in nondispersal accident,
L_1 = Distance transported from the Double Tracks site to the NTS (m),
f_{1i} = Fraction of travel in area i,
t_a = Exposure time of people at the accident scene (s),
A = Total number of different radioisotopes α,
$f_{r\alpha}$ = Fraction of total radioactivity due to radioisotope α,
$\Phi_{er\alpha}$ = External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),
Ψ_{frs} = Risk function for fatal radiation syndrome (Sv^{-1}), and
R_{13f} = Fatalities due to acute radiation sickness,

the risk of fatalities due to acute radiation sickness in people at the scene of the accident is

$$R_{13f} = \sum_{i=1}^{3} N_{6i} \left(f_{1i}\ L_1 \sum_{s=1}^{S} p_{2is}\ f_{2s} \right) \cdot \frac{n_1\ q_{r1}\ F_{sa}}{r_{rmsb}^2}\ t_a \left(\sum_{\alpha=1}^{A} f_{r\alpha}\ \Phi_{er\alpha} \right) \Psi_{frs} . \quad (22)$$

B.1.5.1.2 Early Radiation-Caused Health Effects in Nondispersal Accidents

Early health effects due to bone-marrow syndrome in accidents involving Double Tracks soil transport vehicles are assumed to be mostly nonfatal. Using the symbols

p_{2is} = Linear probability density for an accident of severity s in area i (m^{-1}),
n_1 = Number of shipments of soil from the Double Tracks site,
q_{r1} = Total amount of radioactivity per average shipment (Bq),
f_{2s} = Fraction of waste released in accident of severity s,
r_{rmsb} = Root-mean-square distance for people at the accident scene (m),

F_{sa} = Source shape factor for released and enclosed activity,

S = Number of degrees of accident severity,

N_{6i} = Average number of persons significantly exposed in nondispersal accident,

L_1 = Distance transported from the Double Tracks site to the NTS (m),

f_{1i} = Fraction of travel in area i,

t_a = Exposure time of people at the accident scene (s),

A = Total number of different radioisotopes α,

$f_{r\alpha}$ = Fraction of total radioactivity due to radioisotope α,

$\Phi_{er\alpha}$ = External dosimetry function for radioisotope α ($Sv\ m^2\ s^{-1}\ Bq^{-1}$),

Ψ_{ars} = Risk function for acute but nonfatal radiation syndrome (Sv^{-1}), and

$R_{14\,in}$ = Injuries due to acute radiation sickness,

the risk of acute but nonfatal radiation sickness in people at the scene of the accident is

$$R_{14\,in} = \sum_{i=1}^{3} N_{6i} \left(f_{1i}\ L_1 \sum_{s=1}^{S} P_{2is}\ f_{2s} \right) \frac{n_1\ q_{r1}\ F_{sa}}{r_{rms\,b}^2}\ t_a \left(\sum_{\alpha=1}^{A} f_{r\alpha}\ \Phi_{er\alpha} \right) \Psi_{ars}\ . \qquad (23)$$

B.1.5.1.3 Radiation Cancer Risk due to Nondispersal Accidents

As late effects of radiation exposure, radiation-caused cancer may occur. Taking into account that the radiation dose is the same as before, and using the symbols

p_{2is} = Linear probability density for an accident of severity s in area i (m^{-1}),

n_1 = Number of shipments of soil from the Double Tracks site,

q_{r1} = Total amount of radioactivity per average shipment (Bq),

f_{2s} = Fraction of waste released in accident of severity s,

r_{rmsb} = Root-mean-square distance for people at the accident scene (m),

F_{sa} = Source shape factor for released and enclosed activity,

S = Number of degrees of accident severity,

N_{6i} = Average number of persons significantly exposed in nondispersal accident,

L_1 = Distance transported from the Double Tracks site to the NTS (m),

f_{1i} = Fraction of travel in area i,

t_a = Exposure time of people at the accident scene (s),

A	=	Total number of different radioisotopes α,
$f_{r\alpha}$	=	Fraction of total radioactivity due to radioisotope α,
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
a_{rc}	=	Risk function for cancer due to high dose-rate exposures (Sv^{-1}), and
R_{15c}	=	Cancer risk due to acute radiation exposure,

the cancer risk due to acute radiation exposure of people at the scene of the accident is

$$R_{15c} = \sum_{i=1}^{3} N_{6i} \left(f_{1i} L_1 \sum_{s=1}^{S} P_{2is} f_{2s} \right) \frac{n_1 \, q_{r1} \, F_{sa}}{r_{rmsb}^2} t_a \left(\sum_{\alpha=1}^{A} f_{r\alpha} \Phi_{er\alpha} \right) a_{rc} \; . \tag{24}$$

B.1.5.1.4 Noncancer Radiation Detriment due to Nondispersal Accidents

This scenario is the same as before except for the endpoint, which is noncancer radiation detriment. Using the symbols

p_{2is}	=	Linear probability density for an accident of severity s in area i (m^{-1}),
n_1	=	Number of shipments of soil from the Double Tracks site,
q_{r1}	=	Total amount of radioactivity per average shipment (Bq),
f_{2s}	=	Fraction of waste released in accident of severity s,
r_{rmsb}	=	Root-mean-square distance for people at the accident scene (m),
F_{sa}	=	Source shape factor for released and enclosed activity,
S	=	Number of degrees of accident severity,
N_{6i}	=	Average number of persons significantly exposed in nondispersal accident,
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
f_{1i}	=	Fraction of travel in area i,
t_a	=	Exposure time of people at the accident scene (s),
A	=	Total number of different radioisotopes α,
$f_{r\alpha}$	=	Fraction of total radioactivity due to radioisotope α,
$\Phi_{er\alpha}$	=	External dosimetry function for radioisotope α (Sv m^2 s^{-1} Bq^{-1}),
a_{rd}	=	Risk function for noncancer detriment at high dose rates (Sv^{-1}), and
R_{16d}	=	Risk for radiation detriment at high dose rates,

the cancer risk due to acute radiation exposure of people at the scene of the accident is

$$R_{16d} = \sum_{i=1}^{3} N_{6i} \left(f_{1i} L_1 \sum_{s=1}^{S} P_{2is} f_{2s} \right) \frac{n_1 \, q_{r1} \, F_{sa}}{r^2_{rms\,b}} t_a \left(\sum_{\alpha=1}^{A} f_{r\alpha} \Phi_{er\alpha} \right) a_{rd} . \tag{25}$$

B.1.5.2 Scenarios for Radiation Exposures due to Accidents With Waste Dispersion

It is assumed here that transportation accidents with dispersion involve a significant dispersion mechanism such as a fuel fire. Waste dispersion by wind at reasonable probabilities involves too small a fraction of the waste and too short an exposure duration to lead to substantial effects. The generation of substantial risks requires a dispersion source out of control for a significant amount of time, such as would occur with a fuel fire. In the subsequent modeling of the risk, two basic facts will be ignored: first, that inhalation exposures to radioactive aerosols can, for the most part, be avoided or mitigated by simple, individually taken preventive measures to avoid smoke inhalation; and second, that once the fact of a potential contamination is known, exposures can be avoided or mitigated by administrative measures such as telling the populace to go or stay inside, to close windows, etc. Any effects incurred subsequent to dispersion, such as the secondary effects considered in RADTRAN (Neuhauser and Kanipe, 1992), can almost certainly be avoided or minimized enough to be negligible. These effects will, therefore, not be considered here.

The generic modeling of the atmospheric dispersion cannot be based on site-specific wind and atmospheric stability information such as that contained in wind-roses and STAR arrays. An unweighted average of dispersion in all six Pasquill stability classes will have to suffice. The dispersion calculation is terminated when the time-integrated air-concentration values drop below $1 \bullet 10^{-5}$ of the source term. At that dilution, the standard errors far outweigh the value and further calculation becomes meaningless.

B.1.5.2.1 Early Fatalities due to Inhalation in Dispersal Accidents

Early health effects due to the inhalation of radioactive aerosols in accidents involving Double Tracks soil transport vehicles are assumed to be fatal in only an extremely small fraction of accidents leading to high lung doses and fatalities occurring due to radiation pneumonitis. Using the symbols

p_{3is} = Linear probability density for a severity s fire accident in area i (m^{-1}),
n_1 = Number of shipments of soil from the Double Tracks site,
q_{r1} = Total amount of radioactivity per average shipment (Bq),
f_{3s} = Fraction of waste aerosolized in fire of severity s,
N_q = Number of concentration areas for stability criterion q,
N_{qmax} = Maximum value of N_q for all stability criteria,
f_q = Fraction of time with stability criterion q,
$\chi_{\nu q}$ = Time-integrated air concentration in annulus ν (Bq s m^{-3} Bq^{-1}),
A_ν = Average annular area of time-integrated concentration isopleth ν (m^2),
d_i = Population density in area i (m^{-2}),
S = Number of degrees of accident severity,
L_1 = Distance transported from the Double Tracks site to the NTS (m),
f_{1i} = Fraction of travel in area i,
I_1 = Average inhalation rate of public (m^3 s^{-1}),
f_4 = Fraction of inhaled particles deposited in lung,
A = Total number of different radioisotopes α,
$f_{r\alpha}$ = Fraction of total radioactivity due to radioisotope α,
$\Phi_{ir\alpha}$ = Internal dosimetry function for radioisotope α (Sv Bq^{-1}),
Ψ_{frs} = Risk function for fatal radiation syndrome (Sv^{-1}), and
R_{17f} = Fatality risk due to acute radiation syndrome,

the risk of fatalities due to acute radiation sickness in members of the public at the scene of the accident is

$$R_{17f} = \sum_{i=1}^{3} d_i \left(f_{1i} \; L_1 \sum_{s=1}^{S} p_{3is} \; f_{3s} \right) n_1 \; q_{r1} \left(\frac{\sum_{q=1}^{6} f_q \sum_{\nu=1}^{N_q} A_\nu \; \chi_{\nu q}}{\sum_{q=1}^{6} f_q} \right) I_1 \; f_4 \left(\sum_{\alpha=1}^{A} f_{r\alpha} \; \Phi_{ir\alpha} \right) \Psi_{frs} \; . \tag{26}$$

This equation can be simplified by defining the auxiliary quantities V and B_d, where

$$V \equiv \sum_{i=1}^{3} d_i \left(f_{1i} \; L_1 \; \sum_{s=1}^{S} p_{3is} \; f_{3s} \right) , \tag{27}$$

and

$$B_d \equiv \frac{\sum_{q=1}^{6} f_q \sum_{v=1}^{N_q} A_v \; \chi_{vq}}{\sum_{q=1}^{6} f_q} , \tag{28}$$

leading to the expression

$$R_{17f} = V \; n_1 \; q_{r1} \; B_d \; I_1 \; f_4 \left(\sum_{\alpha=1}^{A} f_{r\alpha} \; \Phi_{ir\alpha} \right) \Psi_{frs} , \tag{29}$$

for the risk from fatal radiation syndrome.

B.1.5.2.2 Early Radiation-Caused Health Effects in Dispersal Accidents

Early health effects due to the inhalation of radioactive aerosols in accidents involving Double Tracks soil transport vehicles are assumed to be mostly nonfatal. Using the symbols

p_{3is}	=	Linear probability density for a severity s fire accident in area i (m^{-1}),
n_1	=	Number of shipments of soil from the Double Tracks site,
q_{r1}	=	Total amount of radioactivity per average shipment (Bq),
f_{3s}	=	Fraction of waste aerosolized in fire of severity s,
N_q	=	Number of concentration areas for stability criterion q,
N_{qmax}	=	Maximum value of N_q for all stability criteria,
f_q	=	Fraction of time with stability criterion q,
χ_{vq}	=	Time-integrated air concentration in annulus v (Bq s m^{-3} Bq^{-1}),

A_v	=	Average annular area of time-integrated concentration isopleth ν (m^2),
d_i	=	Population density in area i (m^{-2}),
S	=	Number of degrees of accident severity,
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
f_{1i}	=	Fraction of travel in area i,
I_1	=	Average inhalation rate of public ($m^3 s^{-1}$),
f_4	=	Fraction of inhaled particles deposited in lung,
A	=	Total number of different radioisotopes α,
$f_{r\alpha}$	=	Fraction of total radioactivity due to radioisotope α,
$\Phi_{ir\alpha}$	=	Internal dosimetry function for radioisotope α (Sv Bq^{-1}),
Ψ_{ars}	=	Risk function for nonfatal acute radiation syndrome (Sv^{-1}), and
$R_{18\,in}$	=	Injury risk due to acute radiation syndrome,

the risk of acute radiation injury in members of the public at the scene of the accident is given by

$$R_{18\,in} = V\, n_1\, q_{r1}\, B_d \; I_1\, f_4 \left(\sum_{\alpha=1}^{A} f_{r\alpha}\, \Phi_{ir\alpha} \right) \Psi_{ars} \,, \tag{30}$$

where the quantities V and B_d are given by equations (27) and (28).

B.1.5.2.3 Radiation Cancer Risk due to Inhalation in Dispersal Accidents

As late effects of exposure due to the inhalation of radioactive aerosols in accidents involving Double Tracks soil transport vehicles, radiation-caused cancer may occur. Using the symbols

p_{3is}	=	Linear probability density for a severity s fire accident in area i (m^{-1}),
n_1	=	Number of shipments of soil from the Double Tracks site,
q_{r1}	=	Total amount of radioactivity per average shipment (Bq),
f_{3s}	=	Fraction of waste aerosolized in fire of severity s,
N_q	=	Number of concentration areas for stability criterion q,
N_{qmax}	=	Maximum number N_q for all stability criteria,
f_q	=	Fraction of time with stability criterion q,
χ_{vq}	=	Time-integrated air concentration in annulus ν (Bq s m^{-3} Bq^{-1}),
A_v	=	Average annular area of time-integrated concentration isopleth ν (m^2),
d_i	=	Population density in area i (m^{-2}),

S	=	Number of degrees of accident severity,
L_1	=	Distance transported from the Double Tracks site to the NTS (m),
f_{1i}	=	Fraction of travel in area i,
I_1	=	Average inhalation rate of public ($m^3 s^{-1}$),
f_4	=	Fraction of inhaled particles deposited in lung,
A	=	Total number of different radioisotopes α,
$f_{r\alpha}$	=	Fraction of total radioactivity due to radioisotope α,
$\Phi_{ir\alpha}$	=	Internal dosimetry function for radioisotope α (Sv Bq^{-1}),
a_{rc}	=	Cancer risk coefficient for high dose-rate exposures (Sv^{-1}), and
R_{19c}	=	Cancer risk due to accidental inhalation exposure,

the cancer risk in members of the public near the scene of a Double Tracks site transportation accident with waste dispersal is given by

$$R_{19c} = V\, n_1\, q_{r1}\, B_d \; I_1\, f_4 \left(\sum_{\alpha=1}^{A} f_{r\alpha}\, \Phi_{ir\alpha} \right) a_{rc} , \qquad (31)$$

where the quantities V and B_d are given by equations (27) and (28).

B.1.5.2.4 Noncancer Health Effects due to Inhalation in Dispersal Accidents

Various health effects, summed up as radiation detriment, due to the inhalation of radioactive aerosols in accidents involving Double Tracks soil transport vehicles are assumed to be mostly genetic and nonfatal. Using the symbols

p_{3is}	=	Linear probability density for a severity s fire accident in area i (m^{-1}),
n_1	=	Number of shipments of soil from the Double Tracks site,
q_{r1}	=	Total amount of radioactivity per average shipment (Bq),
f_{3s}	=	Fraction of waste aerosolized in fire of severity s,
N_q	=	Number of concentration areas for stability criterion q,
N_{qmax}	=	Maximum number N_q for all stability criteria,
f_q	=	Fraction of time with stability criterion q,
χ_{vq}	=	Time-integrated air concentration in annulus v (Bq s m^{-3} Bq^{-1}),
A_v	=	Average annular area of time-integrated concentration isopleth v (m^2),
d_i	=	Population density in area i (m^{-2}),

S = Number of degrees of accident severity,

L_1 = Distance transported from the Double Tracks site to the NTS (m),

f_{1i} = Fraction of travel in area i,

I_1 = Average inhalation rate of public ($m^3\ s^{-1}$),

f_4 = Fraction of inhaled particles deposited in lung,

A = Total number of different radioisotopes α,

$f_{r\alpha}$ = Fraction of total radioactivity due to radioisotope α,

$\Phi_{ir\alpha}$ = Internal dosimetry function for radioisotope α (Sv Bq^{-1}),

a_{rd} = Risk coefficient for noncancer detriment at high dose rates (Sv^{-1}), and

R_{20d} = Risk of radiation detriment due to accidental exposure,

the noncancer risk of radiation detriment in members of the public near the scene of a Double Tracks site transportation vehicle accident with waste dispersal is given by

$$R_{20d} = V\ n_1\ q_{r1}\ B_d\ I_1\ f_4 \left(\sum_{\alpha=1}^{A} f_{r\alpha}\ \Phi_{ir\alpha} \right) a_{rd}\ , \tag{32}$$

where the quantities V and B_d are given by equations (27) and (28).

B.2.0 References

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Appendix C

Parameters Used in the Double Tracks Site Soil Transportation Risk Assessment

C.1.0 Parameters used in the Double Tracks Site Soil Transportation Risk Assessment

This appendix defines the parameters used in the risk assessment for the transportation of soil from the Double Tracks site to the Nevada Test Site. Table C-1 provides a definition for each parameter, and Tables C-2 and C-3 list the numerical value of each parameter and the source of the value.

Table C-1
Definition of Parameters Used in the Transportation Risk Assessment
(Page 1 of 4)

Parameter	Units[a]	Parameter Definition
A	–[b]	Total number of different radioisotopes
A_v	m^2	Average annular area of time-integrated concentration isopleth v
a_{rc}	Sv^{-1}	Cancer risk coefficient for high dose-rate exposures
a_{rd}	Sv^{-1}	Risk coefficient for noncancer detriment at high dose rates
d_i	m^{-2}	Population density in area i
f_{1i}	–	Fraction of travel in area i
f_{2s}	–	Fraction of waste released in accident of severity s
f_{3s}	–	Fraction of waste aerosolized in fire of severity s
f_4	–	Fraction of inhaled particles deposited in lung
f_{10i}	–	Fraction of freeway travel in area i
F_{ac}	–	Attenuation and geometric factors for the transport vehicle crew
F_{ap}	–	Attenuation factor of the transport vehicle for exposure of the public when passing parallel or opposite to the vehicle
F_{ar}	–	Attenuation and geometric factors for the public at rest stops
f_q	–	Fraction of time with stability class q
$f_{r\alpha}$	–	Fraction of total radioactivity due to radioisotope α
F_{sa}	–	Source shape factor for released and enclosed activity
F_{sc}	–	Source shape factor for the transport vehicle crew exposure
g_{10i}	–	Fraction of rush hour travel in area i
h_{10i}	–	Fraction of city street travel in area i
i	–	Population distribution index (rural, suburban, or urban indicator)

Table C-1
Definition of Parameters Used in the Transportation Risk Assessment
(Page 2 of 4)

Parameter	Units[a]	Parameter Definition
I_1	$m^3 s^{-1}$	Average inhalation rate of the public
L_1	m	Transport distance from the Double Tracks site to the Nevada Test Site (public roads only)
L_2	m	Average distance between transport vehicle stops
n_1	–	Number of soil shipments from the Double Tracks site
N_2	–	Average number of people exposed at rest stops
N_3	–	Average number of people in vehicles on the road
N_{4i}	s^{-1}	One-way vehicle count rate in area i
N_5	–	Average number of crew in transport vehicle
N_{6i}	–	Average number of persons significantly exposed in a nondispersal accident
N_q	–	Number of concentration areas for atmospheric stability class q
$N_{q\,max}$	–	Maximum value of N_q for all atmospheric stability classes
p_{1f}	m^{-1}	Linear probability density for a traffic accident fatality
p_{1in}	m^{-1}	Linear probability density for a traffic accident injury
p_{2is}	m^{-1}	Linear probability density for a traffic accident of severity s in area i
p_{3is}	m^{-1}	Linear probability density for a severity s fire traffic accident in area i
q	–	Pasquill atmospheric stability class index
q_{r1}	Bq	Total amount of radioactivity per shipment of Double Tracks site soil
R_{1f}	–	Traffic fatality risk due to Double Tracks site soil transport
R_{2in}	–	Traffic injury risk due to Double Tracks site soil transport
R_{3c}	–	Cancer risk to people living along the transport corridor due to shipment of Double Tracks site soil
R_{4d}	–	Risk to people living along the transport corridor for noncancer radiation detriment due to shipment of Double Tracks site soil
R_{5c}	–	Cancer risk due to exposure of public at roadside rest areas
R_{6d}	–	Risk for noncancer radiation detriment due to exposure of public at roadside rest areas
R_{7c}	–	Cancer risk due to travel parallel to shipments
R_{8d}	–	Risk for noncancer radiation detriment due to travel parallel to shipments

Table C-1
Definition of Parameters Used in the Transportation Risk Assessment
(Page 3 of 4)

Parameter	Units[a]	Parameter Definition
R_{9c}	–	Cancer risk due to travel opposite to shipments
R_{10d}	–	Risk for noncancer radiation detriment due to travel opposite to shipments
R_{11c}	–	Cancer risk due to exposure of the transport vehicle crew during routine transport
R_{12d}	–	Risk for noncancer radiation detriment due to exposure of the transport vehicle crew during routine transport
R_{13f}	–	Risk of fatality due to acute radiation sickness with exposure in nondispersal accidents
R_{14in}	–	Risk of injury due to acute radiation sickness with exposure in nondispersal accidents
R_{15c}	–	Cancer risk due to acute radiation exposure in nondispersal accidents
R_{16d}	–	Risk for noncancer radiation detriment at high doses due to exposure in nondispersal accidents
R_{17f}	–	Risk of fatality due to acute radiation syndrome caused by inhalation exposure in dispersal accidents
R_{18in}	–	Risk of injury due to acute radiation syndrome caused by inhalation exposure in dispersal accidents
R_{19c}	–	Cancer risk due to inhalation exposure in dispersal accidents
R_{20d}	–	Risk for noncancer radiation detriment due to inhalation exposure in dispersal accidents
$r_{i\,max}$	m	Maximum integration distance from transport vehicle in area i
$r_{i\,min}$	m	Minimum integration distance from transport vehicle in area i
$r_{rms\,b}$	m	Root-mean-square distance for people at an accident scene
$r_{rms\,c}$	m	Root-mean-square distance of source (soil payload) to the transport vehicle crew
$r_{rms\,p}$	m	Root-mean-square distance of the public at rest stops
s	–	Number of degrees of accident severity
t_1	s	Average time spent at rest stops
t_2	s	Average time needed for passenger vehicle to close the transport vehicle
t_a	s	Exposure time of people at a nondispersal accident scene
V_{vi}	$m\ s^{-1}$	Transport vehicle speed in area i

Table C-1
Definition of Parameters Used in the Transportation Risk Assessment
(Page 4 of 4)

Parameter	Units[a]	Parameter Definition
x_i	m	Minimum exposure distance in area i
$\Phi_{er\alpha}$	Sv m^2 s^{-1} Bq^{-1}	External dosimetry function for radionuclide α
$\Phi_{ir\alpha}$	Sv Bq^{-1}	Internal dosimetry function for radionuclide α
ϕ_{rc}	–	Dose-rate effectiveness factor for cancer at low dose rates
ϕ_{rd}	–	Dose-rate effectiveness factor for noncancer detriment at low dose rates
Ψ_{ars}	Sv^{-1}	Risk function for acute but nonfatal radiation syndrome
Ψ_{frs}	Sv^{-1}	Risk function for fatal radiation syndrome
χ_{vq}	Bq s m^{-3} Bq^{-1}	Time-integrated air concentration in annulus v

[a] The following notes apply to these units: Bq = becquerel, m = meter, s = second, Sv = sievert
[b] A dash indicates dimensionless parameter

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Parameter	Value	Reference
A	3	Telecon from R. McKinley to R. Sobocinski (IT, 1995)
A_v	See Table D-3	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
a_{rc}	0.04 Sv^{-1}	ICRP[a] Publication 60 (ICRP, 1991)
a_{rd}	0.03 Sv^{-1}	ICRP Publication 60 (ICRP, 1991)
d_i (i = 1)	1.38×10^{-6} m^{-2}	Route-specific output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
d_i (i = 2)	8.98×10^{-5} m^{-2}	Route-specific output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
f_{1i} (i = 1)	0.9968	Route-specific output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
f_{1i} (i = 2)	0.0032	Route-specific output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
f_{2s} (s = 1)	0.01	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 2)	0.1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 3)	1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 4)	1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 5)	1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 6)	1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 7)	1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{2s} (s = 8)	1	Modified from NUREG-0170 Model II release fraction for a Type A package (NRC, 1977)
f_{3s} (s = 1)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_{3s} (s = 2)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_{3s} (s = 3)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_{3s} (s = 4)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_{3s} (s = 5)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)

Table C-2
Numerical Values Used in the Transportation Risk Assessment
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Parameter	Value	Reference
f_{3s} (s = 6)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_{3s} (s = 7)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_{3s} (s = 8)	6.0×10^{-3}	Airborne release fraction for nonreactive powders in response to thermal stress (DOE, 1993)
f_4	0.005	Assumption based on particle size distribution
f_{10i} (i = 1)	0	From HIGHWAY 3.1 routing model (Johnson et al., 1993)
f_{10i} (i = 2)	0	From HIGHWAY 3.1 routing model (Johnson et al., 1993)
F_{ac}	0.001	Assumed attenuation and geometry factor
F_{ap}	0.0001	Assumed attenuation factor
F_{ar}	0.001	Assumed attenuation and geometry factor
f_q (q = a)	0.026	Nevada stability array
f_q (q = b)	0.141	Nevada stability array
f_q (q = c)	0.126	Nevada stability array
f_q (q = d)	0.299	Nevada stability array
f_q (q = e)	0.131	Nevada stability array
f_q (q = f)	0.277	Nevada stability array
$f_{r\alpha}$ (α = Pu-239)	0.848	Telecon from R. McKinley to R. Sobocinski (IT, 1995)
$f_{r\alpha}$ (α = Pu-240)	0.085	Telecon from R. McKinley to R. Sobocinski (IT, 1995)
$f_{r\alpha}$ (α = Am-241)	0.067	Telecon from R. McKinley to R. Sobocinski (IT, 1995)
F_{sa}	0.1	Assumed source shape factor
F_{sc}	0.1	Assumed source shape factor

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Parameter	Value	Reference
g_{10i} (i = 1)	0	Route does not pass through urban areas based on output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
g_{10i} (i = 2)	0	Route does not pass through urban areas based on output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
h_{10i} (i = 1)	0	Route does not pass through urban areas based on output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
h_{10i} (i = 2)	0	Route does not pass through urban areas based on output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
i	2	Index, rural = 1, suburban = 2, route does not pass through any areas classified as urban based on output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
I_1	2.64×10^{-4} m^3 s^{-1}	ICRP Publication 23 (ICRP, 1975)
L_1	299,274 m	Route-specific output from HIGHWAY 3.1 routing model (Johnson et al., 1993)
L_2	91,000 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
n_1	469 1,094	The smaller value is based on a 200 picocurie/gram cleanup level, and the larger is based on a 100 picocurie/gram cleanup level (DOE, 1995)
N_2	25	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_3	2	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_{4i} (i = 1)	1.56×10^{-2} s^{-1}	Route-specific from 1993 Annual Traffic Report (NDOT, 1993)
N_{4i} (i = 2)	3.75×10^{-2} s^{-1}	Route-specific from 1993 Annual Traffic Report (NDOT, 1993)
N_5	2	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_{6i} (i = 1)	4	Assumption
N_{6i} (i = 2)	10	Assumption

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Numerical Values Used in the Transportation Risk Assessment
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Parameter	Value	Reference
N_q (q = a)	6	Number of concentration areas with $\chi_{vq} \geq 10^{-5}$, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_q (q = b)	7	Number of concentration areas with $\chi_{vq} \geq 10^{-5}$, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_q (q = c)	7	Number of concentration areas with $\chi_{vq} \geq 10^{-5}$, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_q (q = d)	7	Number of concentration areas with $\chi_{vq} \geq 10^{-5}$, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_q (q = e)	9	Number of concentration areas with $\chi_{vq} \geq 10^{-5}$, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
N_q (q = f)	11	Number of concentration areas with $\chi_{vq} \geq 10^{-5}$, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
$N_{q\,max}$	11	Maximum value of N_q, RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
p_{1f}	2.70×10^{-11} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993) and Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991)
p_{1in}	2.30×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993) and Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991)
p_{2is} (i = 1, s = 1)	3.56×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 1, s = 2)	2.33×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 1, s = 3)	1.36×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)

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Parameter	Value	Reference
p_{2is} (i = 1, s = 4)	3.11×10^{-11} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 1, s = 5)	9.06×10^{-12} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 1, s = 6)	4.98×10^{-12} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 1, s = 7)	4.40×10^{-13} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 1, s = 8)	8.74×10^{-14} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 1)	3.35×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 2)	2.19×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 3)	1.71×10^{-10} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 4)	3.90×10^{-11} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)

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Numerical Values Used in the Transportation Risk Assessment
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Parameter	Value	Reference
p_{2is} (i = 2, s = 5)	$5.12 \times 10^{-12}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 6)	$1.34 \times 10^{-12}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 7)	$5.18 \times 10^{-14}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{2is} (i = 2, s = 8)	$4.57 \times 10^{-15}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 1)	$1.92 \times 10^{-11}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 2)	$1.25 \times 10^{-11}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 3)	$7.31 \times 10^{-12}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 4)	$1.67 \times 10^{-12}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 5)	$4.88 \times 10^{-13}\ m^{-1}$	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)

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Parameter	Value	Reference
p_{3is} (i = 1, s = 6)	2.68×10^{-13} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 7)	2.37×10^{-14} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 1, s = 8)	4.70×10^{-15} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 1)	1.80×10^{-11} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 2)	1.18×10^{-11} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 3)	9.18×10^{-12} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 4)	2.10×10^{-12} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 5)	2.75×10^{-13} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 6)	7.21×10^{-14} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)

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Numerical Values Used in the Transportation Risk Assessment
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Parameter	Value	Reference
p_{3is} (i = 2, s = 7)	2.46×10^{-16} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
p_{3is} (i = 2, s = 8)	1.92×10^{-11} m^{-1}	Route-specific, calculated from data in the 1993 Annual Traffic Report (NDOT, 1993), Nevada Highways: Physical Conditions and Safety Experience (DOE, 1991), and NUREG-0170 (NRC, 1977)
q_{r1}	$2.71 \times 10^{+08}$ Bq $7.74 \times 10^{+08}$ Bq	Range of radioactivity in a shipment (IT, 1995) and (DOE, 1995)
$r_{i\,max}$ (i = 1)	800 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
$r_{i\,max}$ (i = 2)	800 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
$r_{i\,min}$ (i = 1)	27 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
$r_{i\,min}$ (i = 2)	27 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
$r_{rms\,b}$	3 m	Assumed to be the same as $r_{rms\,c}$
$r_{rms\,c}$	3 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
$r_{rms\,p}$	30 m	Modified from RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
s	8	NUREG-0170 (NRC, 1977)
t_1	3,600 s	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
t_2	2 s	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
t_a	3,600 s	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
V_{vi} (i = 1)	24.44 m s^{-1}	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
V_{vi} (i = 2)	11.11 m s^{-1}	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
x_i (i = 1)	3 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)
x_i (i = 2)	3 m	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)

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Numerical Values Used in the Transportation Risk Assessment
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Parameter	Value	Reference
$\Phi_{er\alpha}$ (α = Pu-239)	3.24×10^{-19} Sv m^2 s^{-1} Bq^{-1}	DOE/EH-0070 (DOE, 1988a)
$\Phi_{er\alpha}$ (α = Pu-240)	7.02×10^{-19} Sv m^2 s^{-1} Bq^{-1}	DOE/EH-0070 (DOE, 1988a)
$\Phi_{er\alpha}$ (α = Am-241)	2.52×10^{-19} Sv m^2 s^{-1} Bq^{-1}	DOE/EH-0070 (DOE, 1988a)
$\Phi_{ir\alpha}$ (α = Pu-239)	6.87×10^{-05} Sv Bq^{-1}	DOE/EH-0071 (DOE, 1988b)
$\Phi_{ir\alpha}$ (α = Pu-240)	6.87×10^{-05} Sv Bq^{-1}	DOE/EH-0071 (DOE, 1988b)
$\Phi_{ir\alpha}$ (α = Am-241)	7.08×10^{-05} Sv Bq^{-1}	DOE/EH-0071 (DOE, 1988b)
ϕ_{rc}	2.5	ICRP Publication 60 (ICRP, 1991)
ϕ_{rd}	4.0	ICRP Publication 60 (ICRP, 1991)
Ψ_{ars}	0.67 Sv^{-1}	WASH-1400 (NRC, 1975)
Ψ_{frs}	0.33 Sv^{-1}	WASH-1400 (NRC, 1975)
X_{vq}	see Table D-3	RADTRAN 4 Technical Manual (Neuhauser and Kanipe, 1993)

[a]ICRP = International Commission on Radiological Protection

Units of measure:
Bq = becquerel
m = meter
s = second
Sv = sievert

Table C-3
Integrated Air Concentration Values, χ_{vq} (Bq s m^{-3} Bq^{-1}), and Average Annular Areas, A_v (m^2), for Pasquill Atmospheric Stability Classes A through F[a]

Area, A_v (m^2)	Pasquill Atmospheric Stability Class					
	A	B	C	D	E	F
	Integrated Air Concentration, χ_{vq} (Bq s m^{-3} Bq^{-1})					
$4.6\times10^{+02}$	6.0×10^{-03}	4.0×10^{-03}	4.0×10^{-03}	4.3×10^{-03}	9.6×10^{-03}	6.2×10^{-02}
$1.5\times10^{+03}$	1.7×10^{-03}	1.3×10^{-03}	1.1×10^{-03}	1.3×10^{-03}	3.2×10^{-03}	1.8×10^{-02}
$3.9\times10^{+03}$	8.4×10^{-04}	5.5×10^{-04}	5.7×10^{-04}	6.5×10^{-04}	1.6×10^{-03}	8.4×10^{-03}
$1.3\times10^{+04}$	1.7×10^{-04}	1.3×10^{-04}	1.3×10^{-04}	1.8×10^{-04}	4.0×10^{-04}	2.0×10^{-03}
$3.0\times10^{+04}$	7.8×10^{-05}	6.0×10^{-05}	6.7×10^{-05}	9.5×10^{-05}	2.1×10^{-04}	9.2×10^{-04}
$6.9\times10^{+04}$	2.8×10^{-05}	2.7×10^{-05}	3.0×10^{-05}	4.3×10^{-05}	1.4×10^{-04}	4.4×10^{-04}
$1.8\times10^{+05}$	–[b]	1.0×10^{-05}	1.0×10^{-05}	1.8×10^{-05}	4.4×10^{-05}	2.0×10^{-04}
$4.5\times10^{+05}$	–	–	–	–	2.1×10^{-05}	1.0×10^{-04}
$8.6\times10^{+05}$	–	–	–	–	1.2×10^{-05}	6.2×10^{-05}
$2.6\times10^{+06}$	–	–	–	–	–	2.6×10^{-05}
$4.5\times10^{+06}$	–	–	–	–	–	1.9×10^{-05}

[a]From *RADTRAN 4 Technical Manual* (Neuhauser and Kanipe, 1993).
[b]A dash indicates that the integrated air concentration is considered negligible (<10^{-05}).

Units of measure:
Bq = becquerel
m = meter
s = second
Sv = sievert

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